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Vol. 33 • Issue 1

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- Long eye relief
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january 05

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ADOLF SCHALLER

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Water in Mars' past, a comet flyby, and the first Neptune-size exoplanets yet — these and other astronomy stories made headlines in 2004. FRANCIS REDDY

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ON THE COVER
Gigantic solar flares and eruptions — the most powerful known in 30 years — burst forth in October–November 2003 and reverberated to the solar system's edge in 2004. These "Halloween storms" were just one of the 10 top astronomy stories of the last year. Learn more — and check out the others — starting on page 31. SOHO-EIT

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SECOND LIGHT: See animations of star formation.

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LUCIFER'S PLANETS: Learn the basics about the known extrasolar planets.

LURE OF THE PLEIADES: Enjoy more dazzling photos of this beloved star cluster.

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BY DAVID J. EICHER

A big year for astronomy

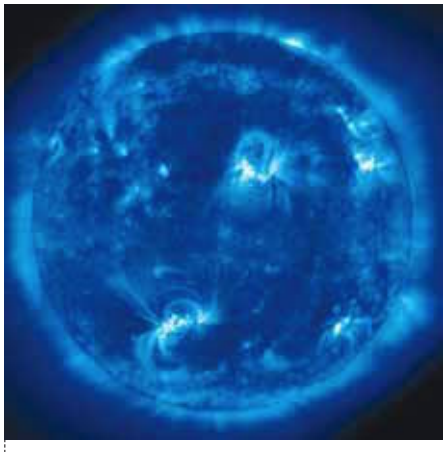
The cosmos holds many mysteries,

and every year, astronomers solve a few of them. This past year saw tremendous strides in astronomy and far more exciting results than we might have expected. There were complete surprises, as with the Halloween storms of 2003: Three of the most powerful solar flares recorded blasted satellites and Earth's power grid in a burst of activity called "extraordinary" by solar scientists. "Exo-Neptunes," each weighing less than 25 Earth masses, were discovered orbiting nearby stars. The cold, dark loneliness of the outer solar system was revealed to harbor a new partner, dubbed Sedna, the most-distant body ever observed in our star's family of objects.

Planetary missions also provided excitement in the astronomy world last year. An all-out assault on Mars by rovers Spirit and Opportunity resulted in the discovery that water flowed on the Red Planet in the distant past. Meanwhile, the Cassini-Huygens spacecraft reached Saturn and immediately found surprises — radiation belts that extend down to the cloud tops, and patches of water ice and carbon dioxide on Phoebe.

Still other missions, Genesis and Stardust, were designed to sample particles in the solar system and return them to Earth. Although it crashed into the Utah desert, Genesis returned pristine subatomic particles from the solar wind. Stardust, having retrieved dust from Comet Wild 2, will return to Earth in 2006.

The spectacular transit of Venus last June was the first such event since 1882. NASA experienced trouble when it declared that, due to fears about shuttle flights and their safety, it would not service Hubble but simply allow its orbit to decay. The American public's reaction forced NASA's strategy to change. In the same year, the nation's observatory produced the deepest view of the cosmos to date: the Hubble Ultra Deep Field.



ACTIVE REGIONS CHURN, ready to unleash energy, in this ultraviolet image of the Sun. SOHO-EIT

Other stories surprised and amazed us during the past year. So many of them were memorable that we created "The year in astronomy," a sweeping overview of the year's top stories written by associate editor Francis Reddy and appearing on page 31.

Few would necessarily agree on the priority of these discoveries. Are there other big stories you would like to see recognized as major events of the year? For more information on astronomy's big year, see www.astronomy.com, and let us know your opinions — we'll be waiting.

Yours truly,

Dave Eicher
Editor

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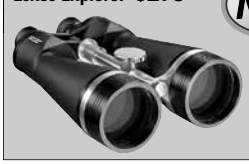

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Looking for answers

Thank you for Francis Reddy's answer

to the question on the term "right ascension" in "Ask Astro" (October 2004). I've taught high-school astronomy for 15 years and have always wondered where the term originated. I have a large selection of college textbooks, but none gives the source of the phrase. Now I can explain the term and make it more meaningful for the students. **— BILL MORGAN,** EVERETT, WASHINGTON

Thanks for your explanation of "right ascension." I have been asked that question in the astronomy class I teach on several occasions. As you said, the older term "oblique ascension" is so obscure that many professional astronomers, myself included, have never heard of it!
— WAYNE HARRIS-WYRICK, OKLAHOMA CITY

Inside gas giants

In "Ask Astro" (October 2004), Richard Crowe answers a question on the interiors of giant planets. He claims Jupiter has a 10 Earth-mass rocky core. While this is a simple and concrete answer, the real answer is we don't know if Jupiter has a core, much less its precise mass.

Deficiencies in our knowledge of the hydrogen equation of state at the high pressures and temperatures at the center of giant planets mean it is not yet possible to know how large Jupiter's core is.

A paper by D. Saumon and T. Guillot in *The Astrophysical Journal* (July 10, 2004) describes how current knowledge of the hydrogen equation of state (based on laser and gas-gun shock experiments) implies that while Saturn's core is probably between 10 and 20 Earth masses in size, Jupiter's structure implies a core less than 3 Earth masses in size.

This difference between Jupiter and Saturn reveals a potential difference in either the formation and/or evolution of the two gas giants. This is a current and exciting question in the field of planetary science, and one that Crowe overlooks.
— JASON BARNES, TUCSON, ARIZONA

PLANETARY SCIENTISTS continue to study the nature and mass of Jupiter's core. NASA/JPL

Thanks to Mr. Barnes for drawing my attention to this interesting article; it provides new information for a planetology class I will teach this spring. In light of this, I should have said Jupiter has a possible *core of under 10 Earth masses.*

My source for the information I presented about Jupiter's core (which is probably much smaller than Saturn's) was William Hubbard, who does research on planetary interiors and whose articles and monographs on this subject have been cited widely in astronomy textbooks.

Although it seems unlikely Saturn has a core and Jupiter does not, it is important to convey the excitement of new discoveries and show that planetary science is a dynamic field of study. **— RICHARD CROWE,** UNIVERSITY OF HAWAII AT HILO

Continuing education

Bob Berman's "Cosmological chaos" (July 2004) was super! The arrogance of human ignorance is often as mind-boggling to me as the universe itself. Berman did a wonderful job of putting this into perspective: The more we learn, the more our mere existence becomes a miracle.

When I ponder this, I am brought back to the various reactions of reverence and awe that Apollo astronauts had when they stepped out of the lunar lander and looked up to see Earth orbiting above them.

The simple fact that we have the ability to put together incorrect theories is a testament to how amazing our place is in this giant cosmos. **— DEAN POLL,** ELY, MINNESOTA

Night vision

I want to recommend a device that transforms the viewing of a meteor shower like no other. At the peak of the 2002 Leonid shower near San Jose, California, I observed roughly 2 meteors per second with the naked eye. Using US Night Vision's PVS-7B 3rd-generation night-vision goggles, I watched 10 to 20 meteors continually rain down to the horizon within the field of view — a stunning sight. **— MIKE KREIN,** SUNNYVALE, CALIFORNIA

Correction

In Francis Reddy's "The star-splitting jets of supernovae" (October 2004), remarks attributed simply to Wheeler were from J. Craig Wheeler of the University of Texas at Austin. **— *ASTRONOMY* EDITORS**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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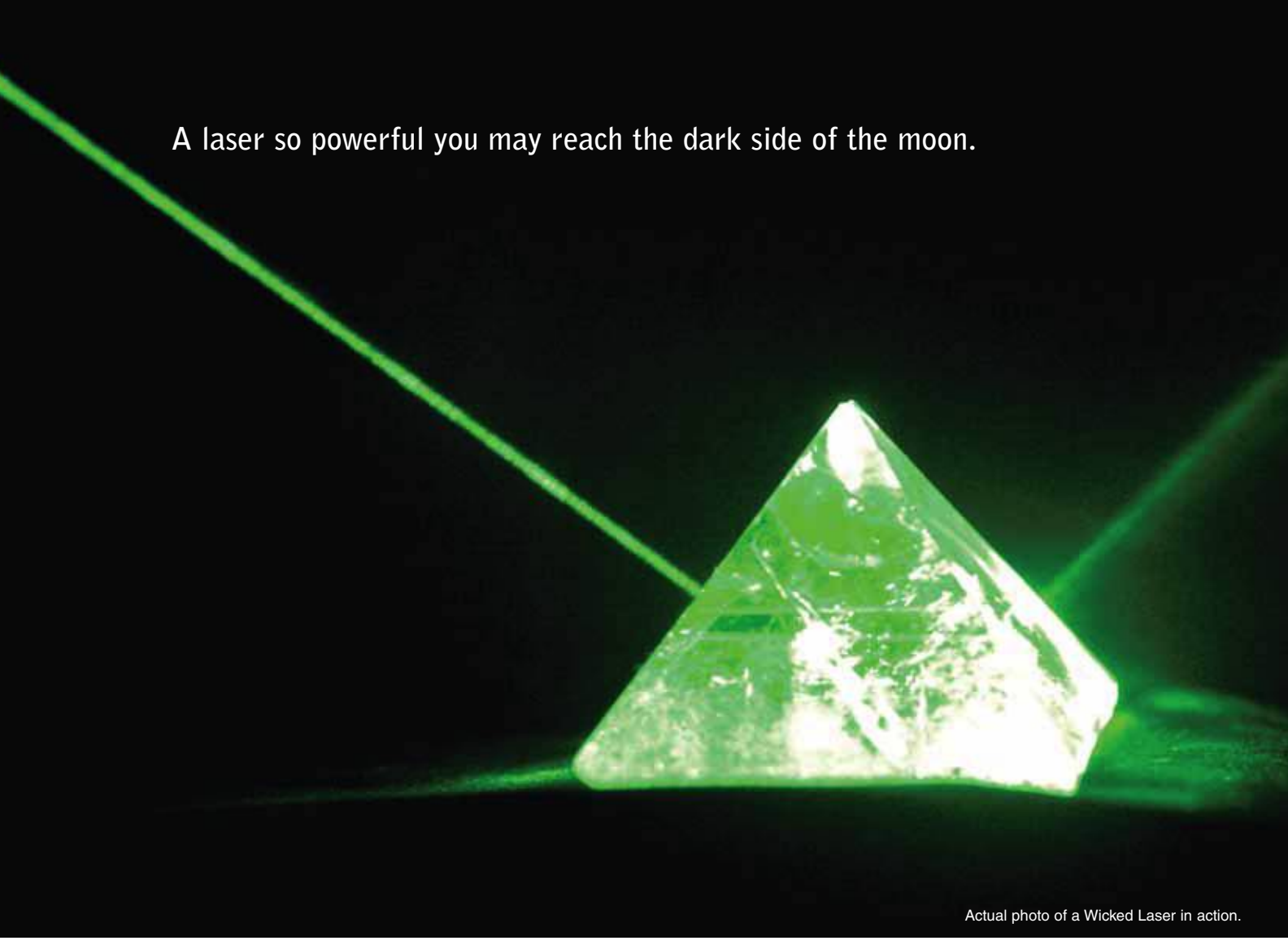

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THE POINT OF IMAGINATION

BY BOB BERMAN

Stand back, Edison

Isn't it exhilarating to roam among the armada of telescopes at a star party, seeing hundreds of backyard enthusiasts spread over a rural site like the Mongol horde? « Gadgets always attract attention. You've seen those green lasers beamed into the sky pointing out constellations, or tried a home-built binocular telescope. It's

a pleasure to drool at the gotta-have-it equipment you know you'll buy eventually.

With so many serious backyard amateurs in the United States alone, there's a steady demand for innovative astronomy-gadgets. Not enough companies exploit this market. So here are 15 suggestions:

1. The Incapacitator This device shoots a disabling microwave beam at any car with headlights aimed at your dark site.

2. The Ultra Lightweight Mount Forget "portable" mounts that weigh 1,200 pounds. Within its tripod, this mount has a thick rubber balloon filled with helium gas. The mount weighs less than nothing for transportation. A valve releases the gas into a portable tank for refilling when the night is over.

3. The TTT Unlike the VLT, the Very Large Telescope, this is a Truly Tiny Telescope. Its 8-inch mirror has an f-ratio of 0.5, so the tube is only 4 inches long. When you're finished, the mirror slips into an old vinyl record jacket, and the telescoping fiber rods fit into a billfold-size box.

4. Belladona Eyedrops Astronomers used these as recently as the late 19th century. They dilate the pupil beyond its usual 7-millimeter limit, letting extra light hit the retina. Downside: Strange health consequences and you look like a lemur.

5. The Neighbor-Brainwashing Tape This idea comes from *The Manchurian Candidate*. It's a CD that plays subliminal messages through your neighbor's TV, suggesting 300,000 times, "Yard lights bad. Darkness good."

6. The Anti-Subtlety Device Some people gaze through scopes at smudgy galaxies and just don't grasp the thrill of seeing barely there blotches. This attachment creates garish kaleidoscopic patterns through the eyepiece. You tell them it's the Hippie Nebula.

7. Charcoal-Grill Lighter/Mirror Kit Remember when we were kids, how we liked to burn holes using the Sun and a magnifying glass? Well, it's *still* fun. An 8-inch telescope mirror will set black paper aflame in seconds. The kit includes a fire extinguisher and an insurance policy.

8. Lecture Disrupter Here's a sound box with control buttons to release boos, catcalls, or raspberries whenever an astrologer is lecturing about the influence of Mars, or a cosmologist attempts to explain the inexplicable Big Bang.

9. The Black-Eye Gag Novelty stores used to sell little fake telescopes that would give the unsuspecting victim a "black eye" after using it. Let's bring this one back with the observing stool and a built-in whoopee cushion. There aren't enough stupid laughs at today's star parties.

10. Bad-Seeing Remover We know how everything is *supposed* to look if only poor seeing wouldn't criminally blur the image. These transparencies project a sharp image onto the focal plane. Friends will never know they're viewing a slide.

11. Scope Cannon Even though muggers never attack astronomers because they know we're broke, some beginners might be wary. This attachment lets the telescope tube fire paintballs. They can knock an attacker backward, providing plenty of time to flee with 250 pounds of equipment.

12. Two-Way Mirror This reflector's optical coating makes it both transparent and reflective, letting you see through the telescope in either direction, like those sneaky "security" mirrors in some stores. It lets you watch observers' faces while they're using the instrument.

13. Minus-Power Eyepiece This instrument shrinks instead of amplifying. It helps sprawling, unwieldy constellations like Hydra or Ophiuchus fit into your telescope's field of view.

14. Anti-Insect Accessory Imagine a telescope's extension tube with a built-in bug zapper. Dead mosquitoes fall down to the mirror, then slide off and out a slot. Drawback: can cause heart attacks when a monster suddenly enters a lunar crater.

15. Dark-Site Subscription Service You receive e-mailed lists telling you of newly abandoned toxic-waste dumps and deserted factory towns. Flat ground and no lights, but some of the places smell funny.

Entrepreneurs: Feel free to use these ideas. They're not yet patented. A

Whoopee gag: Let's bring this one back with the observing stool and a built-in whoopee cushion. There aren't enough stupid laughs at today's star parties.

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BY GLENN CHAPLE

Observing logs

Occupying the shelf of a bookcase in my study is a set of blue three-ring binders. These are my astronomy logbooks. Covering 35 years, they document a lifetime of astronomical adventures. An entry March 27, 1971, describes my first sighting of the planet Mercury. Another entry excitedly recounts a total solar eclipse

viewed from Prince Edward Island July 10, 1972. Even rarer celestial events are recounted through notes and drawings: Mars occulting (passing in front of) the bright star Epsilon (ε) Geminorum in April 1976; a battle-scarred Jupiter after its bombardment by Comet Shoemaker-Levy 9 in July 1994; and, of course, last June's transit of Venus.

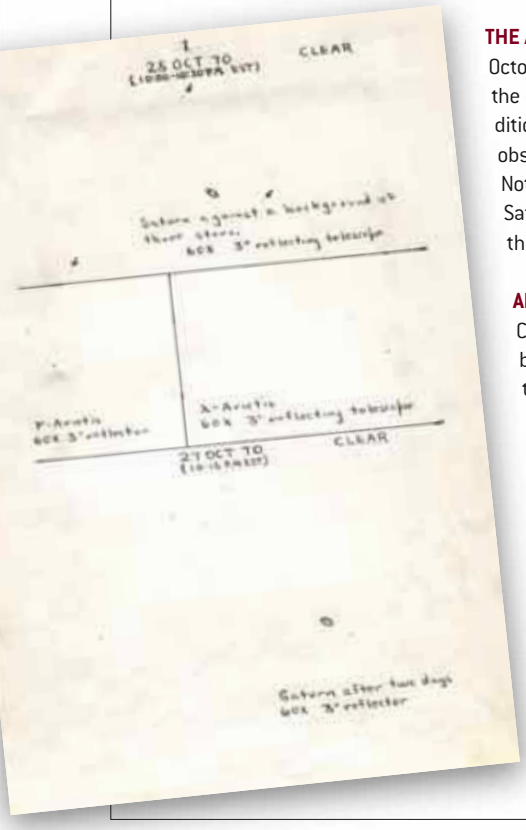
Descriptions of epic cosmic events are interspersed with sketches and comments pertaining to everything from lunar craters to remote galaxies and quasars. Sunspots, planets, comets and asteroids, variable stars (thousands of recorded estimates), double stars, clusters, nebulae — they're all there! My astronomy logbooks have become a valued record and indispensable reference — often referred to when I'm preparing this column.

If you're just getting started in backyard astronomy, you'll want to set up a logbook of your own. To record and store your sketches and notes, try using a standard three-ring binder filled with alternating pages of lined and unlined paper.

What you include with each entry is up to you. It's a good idea to accompany any sketch with the date and time of your observation, sky conditions, optical equipment used, and pertinent notes (location, ease of visibility, etc.).

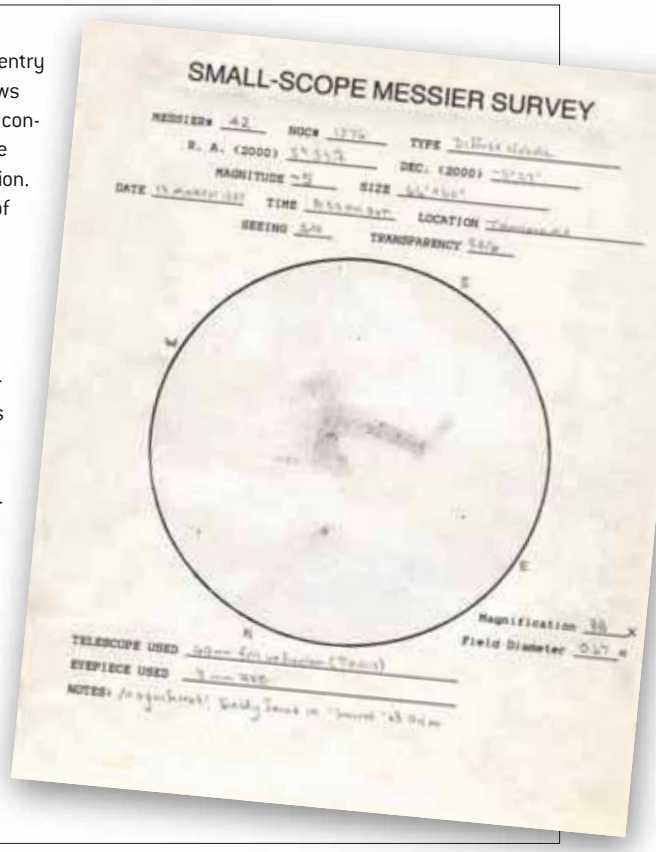
Examples culled from my logbooks and reproduced on this page might help you design your own format. Start keeping an astronomy logbook now, and in time, you'll have a treasured record to enjoy reading on those cloudy nights when you can't observe.

Next month: What's in a name? We look at the nomenclatures astronomers use to identify stars and deep-sky objects.



THE AUTHOR'S logbook has evolved since his first entry October 25, 1970 (left). For this entry, Chaple shows the date of the observation, the time, and the sky conditions. He also includes a short description of the observations and records the telescope information. Notice the arrow to the star on the bottom right of Saturn. In later observations, Chaple discovered this star was, in fact, one of Saturn's moons.

ALMOST 30 YEARS LATER, you can see how Chaple's observing-log entries (right) have become more specific and more organized. For this particular night, Chaple knew what he was going to observe, so he prepared a sheet to include information like the Messier number, type of object, right ascension (R.A.), declination (Dec.), magnitude, and size. He also included the date, time, and location for this observation. Notice his own scale for seeing conditions. On this night, Chaple rated the seeing as 5/10. Around the circle, he marked the directions, then sketched in his view of M42 and its surroundings. He even included general notes on the observation: "Magnificent! Easily found in 'sword' of Orion."



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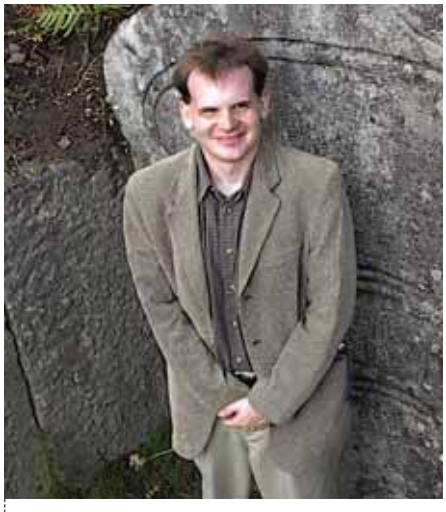
BY WILLIAM SCHOMAKER

Christopher Conselice

Like a classic pioneer, Christopher

Conselice headed west to pursue a golden opportunity. Three years ago, he left the Hubble Heritage Team at the Space Telescope Science Institute in Baltimore to join the astronomy department at the California Institute of Technology as a postdoctoral fellow. He took with him a list of published discoveries one might expect from a 30-year veteran of the field rather than a 30-year-old upstart astronomer.

As head of the Palomar Infrared Survey, he probes the structures of galaxies with the historic, 200-inch Hale Telescope and examines the way light and mass are distributed throughout — rather than treating the galaxies as uniform objects.



AS CHRISTOPHER CONSELICE learns more about galaxy formation, so does the rest of science. PHOTO COURTESY OF CHRISTOPHER CONSELICE

What is it about galaxy formation that captures your interest?

We've been asking the wrong questions about galaxy formation for a long time. Throughout the history of the field, most astronomers who worked on galaxy formation saw galaxies as point-like objects without any detail. Galaxies have rich structures that can reveal much about their formation and history. So, to me, the way astronomers previously studied galaxies seemed like a biologist or botanist trying to understand evolution without any knowledge of animal or plant anatomy.

Apart from asking the wrong questions, why is our present understanding of galaxy formation so poor?

It's a combination of several factors. The first is that the history of galaxy formation is quite complicated and is, in fact, a relatively new area of research. We're just starting to examine distant galaxies as individual systems.

Another reason is that there are observational biases to overcome. The distant galaxies we're able to see from Earth necessarily have a high surface brightness — or a high amount of light emitted per surface area. This makes them easy to detect, but if you placed nearby galaxies at the same distances, they would be very hard to see. So we really don't know if we're detecting an entire galaxy population or just the tip of a huge iceberg.

How many ways can you build a galaxy?

Galaxies form when stars form. And star formation can be triggered in several ways. One way, the most common today, is through accretion of intergalactic gas. Infalling gas becomes compressed to the point that new stars will form. Another way [to make a galaxy], more common in the past, is [for] two galaxies [to] merge together to form a larger system.

Which is the more compelling question about galaxy formation: "when" or "how"?

We know much more about *when* galaxies form than we do about *how* they form. Historically, the way to explain how galaxies form was to compare [galaxies we can observe] with theoretical model predictions. Throughout the last decade, I've been pioneering a different approach, whereby galaxy formation can be studied empirically. When we look at distant galaxies, we are seeing them [as young galaxies]. You can't do this with stellar or biological evolution because the only objects you can study are the final products of the evolution.

Tell us more about your empirical approach and what you've discovered.

One of the things my collaborators and I have discovered is that the stellar-light distributions of galaxies directly correlate with their formation histories. One result is that the degree of asymmetry in a system correlates with the presence of merging activity. The asymmetry parameter is a measure of how symmetric a galaxy is. We measure the parameter by rotating a galaxy's image 180° from its center and subtracting the original from the rotated image. If a galaxy is symmetric, nothing will remain after this rotation and subtraction. If the galaxy is asymmetric, then quite a bit of light will remain.

We've found galaxies that have a high degree of asymmetry are involved in galaxy-galaxy mergers, and furthermore, these mergers are more common in the early universe, which explains how many galaxies must have formed. We've just started along this line of research, however, and much remains to do and discover.

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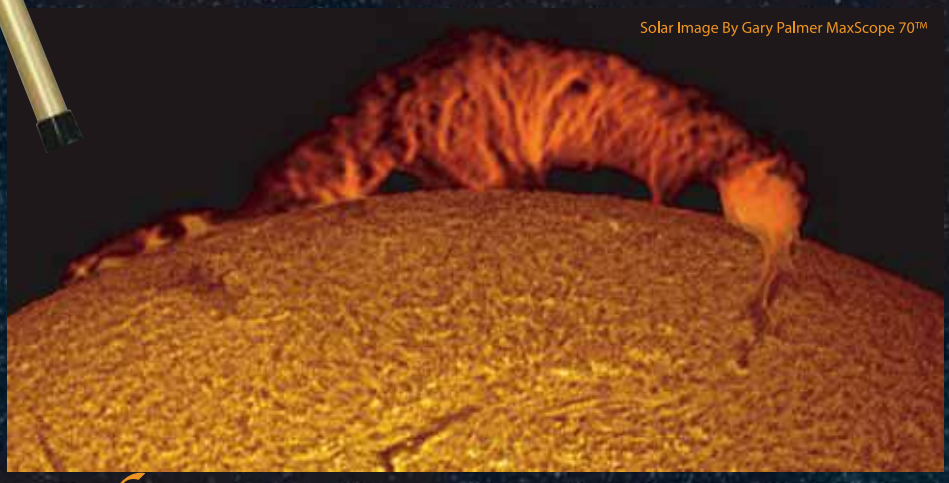
"I have just taken delivery of my PST. WOW,it was well worth the wait. I'm hooked!"
-Peter Buckingham

"I received my PST on July 29, 2004. I was really amazed by the quality of the pictures given by the PST. I just would like to congratulate you and all the Coronado staff to have created the Personal Solar Telescope."
-Carel Caumartin



Solar Image By Gary Palmer MaxScope 70™

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{THREE AWARDED}

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No Purchase Necessary. The official start date for the Astronomy Winter 2004 Sweepstakes is September 24, 2004. Official entry forms are bound in the November, December 2004 and January 2005 issues of Astronomy. The Astronomy Winter 2004 Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependants and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and participating sponsors are not eligible to participate.

Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, zip and telephone number on a postcard and sent it to: Astronomy Winter 2004 Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. Or enter online at www.astronomy.com by filling in the Online Entry form and hitting the SEND key. The Online Entry form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the Astronomy Winter 2004 Sweepstakes is January 7, 2005, and all entries must be transmitted or postmarked no later than that date.

Prizes and Odds of Winning. One drawing will be held on or about January 31, 2005, for the following awards: One Grand Prize consisting of a 14" LX200™ GPS Telescope with Smart Mount™ (retail value $5,345.00). One First Prize consisting of an 8" LX90 Telescope with UHTC™ (retail value $1,870.00). One Second Prize consisting of a LXD75™ SN-8AT Telescope (retail value $1,074.00). Three Third Prize consisting of Deep Sky Imager™ with Autostar Suite ™ (retail value $299.00). Three Fourth Prizes consisting of Nightview™ (retail value $299.00). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for Astronomy Magazine is 145,473. Sweepstakes void in Quebec and void where prohibited.

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A BADLY ENGINEERED deceleration sensor has been identified as a likely culprit in the crash landing of the Genesis spacecraft. Stardust's comet-sample return capsule, due back in 2006, has its sensor correctly placed.

news 01

Read all about it: NASA's latest batch of new ideas, dealing with a balky antenna at Mars, a big telescope aims wide and deep, and how far away the Pleiades cluster really is.

GASSY BUBBLES. Shells of gas in a repeating pattern surround the Cat's Eye Nebula (NGC 6543) in Draco, while delicately colored, intersecting circles lie at its center. The glowing features indicate changes in the evolution of the planetary nebula, a favorite among backyard astronomers. NASA/ESA/HEIC/HUBBLE HERITAGE TEAM

STELLAR ASTRONOMY

Dying star's heartbeat changes its rhythm

A thousand years ago, the dying star in the Cat's Eye Nebula changed how it ejects material. For about 15,000 years, it threw off highly regular gas shells, then the star began to blow off-center gas bubbles deep in the nebula. These bubbles now make up the nebula's "eye," while clouds of material shadowing the star's light produce radial streamers in the shells.

In 2001, a team of astronomers led by Bruce Balick (University of Washington) examined archival Hubble Space Telescope images and found regular rings around the nebula. They attributed these to extremely smooth gas pulses ejected by the central star. In 2004, Romano Corradi (Isaac Newton Group of Telescopes, Spain) and colleagues used the Nordic Optical Telescope to take deep exposures of the nebula. These revealed a few additional rings, pushing the number to at least 11. Each ring is the trace of a spherical shell projected onto the sky.

According to astronomers, as the central star aged, convulsions seized it at approximately 1,500-year intervals, with each seizure ejecting a shell. Corradi and his colleagues suggest such shells may be common in planetary nebulae. But whether the shells are pulsed when thrown off, or are shocked regularly from within, remains unknown. — ROBERT BURNHAM

26 Gigantic collision of galaxy clusters

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29 Revived Mars rovers find signs of water

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THE YOUNG JUPITER MIGRATED SUNWARD by millions of miles, suggest astronomers who studied the Hilda family of asteroids. Simulations show a migrating Jupiter's gravity could have built the group from unrelated asteroids.

EXTRAGALACTIC ASTROPHYSICS

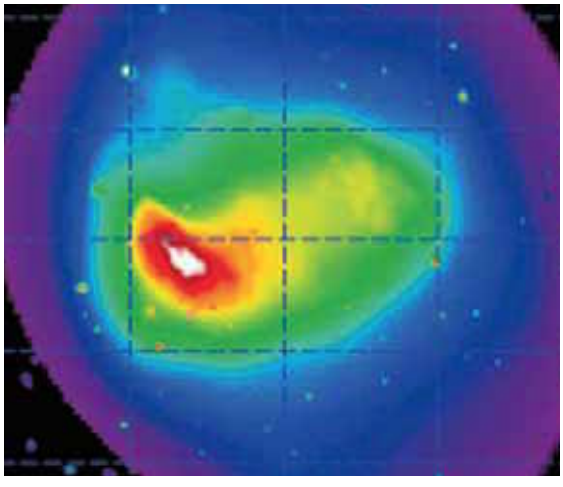
Galaxy clusters collide

A gigantic collision between two galaxy clusters has been caught by astronomers at X-ray wavelengths using the European Space Agency's XMM-Newton satellite observatory. The collision, the astronomers say, is the largest ever studied in detail. It involves more than a thousand galaxies containing trillions of stars, large quantities of hot gas, and still more unseen dark matter.

"Today's cosmic weather report shows a violent storm a million light-years across, as two high-pressure regions collide in a nearby galaxy cluster," says team leader J. Patrick Henry (University of Hawaii). The other team members are Alexis Finoguenov and Ulrich G. Briel (Max Planck Institute for Extraterrestrial Physics, Germany). Their results will be published in *The Astrophysical Journal*.

If we could see the hot, stormy region by eye, it would cover about half the Full Moon's size. The collision spans several million light-years and involves two galaxy clusters that are part of a larger galaxy cluster called Abell 754. The colliding clusters contain about 1,000 and 300 galaxies, respectively.

According to Finoguenov, one cluster has already smashed into the other and made one pass through it. "Now," he says, "gravity will pull the remnants of this first cluster back toward the core of the second." He predicts the two will merge into one larger cluster in about 7 billion years. — **R. B.**



COSMIC CRASH. Two galaxy clusters merge in this X-ray image from XMM-Newton. The larger cluster appears white; the smaller (in yellow) lies at about 2 o'clock. ESA/P. HENRY ET AL.

GALACTIC ASTRONOMY

Last new cluster?

A "new" globular cluster has been discovered in the dusty disk of the Milky Way by a group of astronomers using the Spitzer Space Telescope.

"It's like finding a long-lost cousin," says Chip Kobulnicky (University of Wyoming), leader of the research team. "We thought all the Milky Way's globulars had already been found."

The cluster lies about 9,000 light-years away in Aquila and has a mass of some 300,000 suns. It joins about 150 other globulars in the galaxy.

Although found with Spitzer, the cluster had been seen in earlier surveys but overlooked. — R. B.

NEW AND OLD. This ancient globular lies hidden behind the Milky Way's dust. NASA/JPL-CALTECH

STELLAR ASTRONOMY

How far is the Pleiades?

In 1987, the Hipparcos astrometry satellite placed the Pleiades star cluster 10-percent closer to Earth than previous measurements. The result caused a lot of debate among astronomers.

New work, however, shows the Hipparcos distance was wrong because the brightness of the cluster's stars confused the satellite's sensors.

A member of the Hipparcos team, Floor van Leeuwen (University of Cambridge in England) examined the data and found the Pleiades partially blinded Hipparcos with many bright stars in one of its two "eyes." In effect, the sensors averaged all Pleiades stars instead of picking one or two.

FAR, FAR AWAY. New results show the Pleiades lies 440 light-years away. JOHN CHUMACK

Says Van Leeuwen, "This was a new technique, which failed only very locally. The vast majority of data in the Hipparcos catalog is correct." — **BAS DEN HOND**

FUTURE CONCEPTS

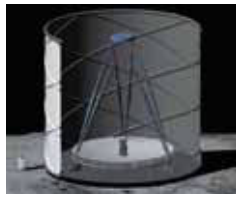
NASA's latest, hottest ideas

The NASA Institute for Advanced Concepts has chosen 12 project proposals for study. The new ideas include using a pinhole space telescope to find extrasolar planets, a liquid-mirror telescope on the Moon (see photo), and a way to protect manned bases on the lunar surface from harmful space radiation.

The pinhole exoplanet finder envisions placing in space an opaque, football-field-size "starshade" with a 30-foot (9 meter) hole. Tens of thousands of miles behind the starshade flies a second spacecraft with imaging detectors. Together, they make a huge pinhole camera with near-perfect optics.

The electrostatic shield for a Moon base would deflect incoming charged particles by generating positive and negative electrical fields above the structure.

These proposals deliberately push the limits of science and technology. Those that survive the study will be funded for a more detailed evaluation looking at their feasibility. — **R. B.**



LIQUID MIRROR. Spinning mercury could form the primary mirror for a lunar telescope. NASA/UNIV. ARIZONA

STELLAR ASTRONOMY

Kepler's supernova turns 400

The last supernova to detonate in the Milky Way appeared in Earth's skies October 9, 1604, just a few years before the telescope was invented. Astronomer Johannes Kepler measured the star's position and estimated its changing brightness. Thus, it has long been known as Kepler's supernova.

BIG BANG. Kepler's supernova was the last visual supernova to explode in the Milky Way. It lies 13,000 light-years away in Ophiuchus. NASA/ESA/JHU

Four centuries later, the remnant's diameter is 14 light-years, and it's expanding at 4 million mph (6 million km/h). A team of astronomers used the Chandra X-ray Observatory, the visual Hubble Space Telescope, and the infrared Spitzer Space Telescope to study the expanding gas cloud.

Rich in iron, the supernova shell is sweeping up interstellar material, some of it shed by the progenitor star before it exploded. Spitzer's data (colored red in the image) shows warm dust, while data from Chandra (blue and green) and HST (yellow) reveal hotter gas.

The yellow regions show where the shock wave has torn through the densest regions of gas, while the blue areas (denoting the highest temperatures) lie directly behind the shock wave.

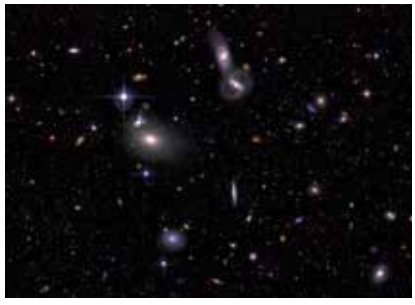
Says team member Ravi Sankrit (Johns Hopkins University), "Multi-wavelength views are essential for putting together a picture of how supernova remnants evolve." — **R. B.**

COSMOLOGY

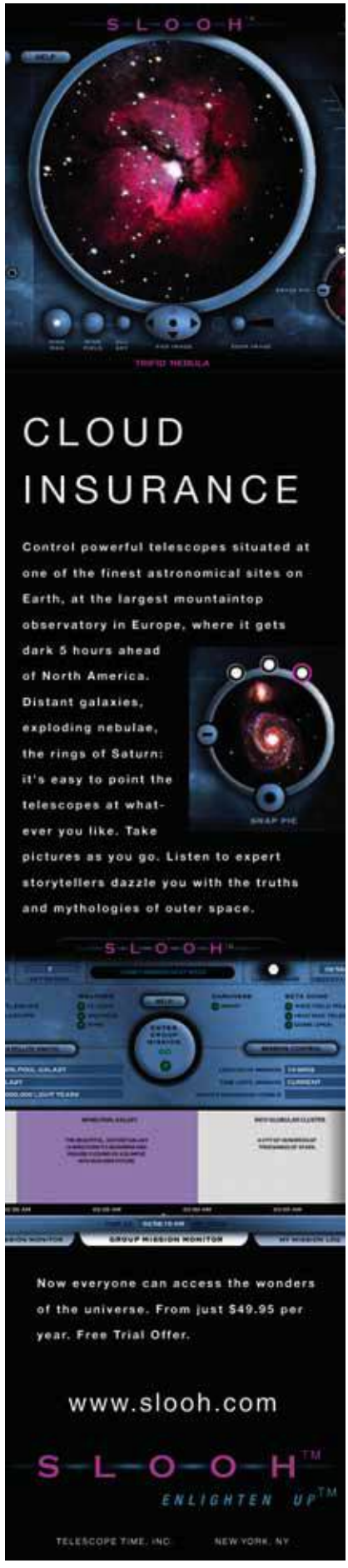
Going wide, going deep

A quarter-century after it was dedicated, the 3.2-meter (105 inch) Canada-France-Hawaii Telescope (CFHT) produces some of the best wide-field and high-resolution images of the universe from the ground. The telescope is at one of the world's best locations (Hawaii's Mauna Kea), but the key ingredient is a 340-megapixel digital camera called MegaCam, built in 2003. The instrument mosaics 36 CCD imaging chips to cover an area of sky 1° square, or twice the Full Moon's width.

In 2003, MegaCam and CFHT began a multi-year project called the Canada-France-Hawaii Telescope Legacy Survey. About 500 nights spaced over 5 years will be spent on three surveys. They will examine the entire ecliptic band, three selected sky regions, and four deep fields. The surveys' first data will be available for researchers in August 2006, but selected images were released in early October on the telescope's 25th anniversary. — **R. B.**



SEEING FAR AND WIDE. Dozens of galaxies scatter across this image from one of CFHT's deep survey frames. CFHT/TERAPIX/IAP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COSMOLOGY

Can Hubble see the earliest galaxies?

Astronomers met at the Space Telescope Institute in Baltimore in September to discuss the Hubble Ultra Deep Field (HUDF) photo released in March. Structures in the image, they say, show the earliest star-forming galaxies ever seen — objects about 95 percent of the way back to the Big Bang.

LIGHTS OF DAWN. Astronomers are questioning if the Hubble Ultra Deep Field captured galaxies at the end of the cosmic "Dark Ages." NASA/ESA

"We see here a complex array of objects," says Steve Beckwith, the institute's director. "They're faint, fuzzy things at the edge of the universe."

But there's controversy over what these galaxies signify. Astronomers studying them seek to map the reionization epoch — when the universe became transparent following an earlier era, the "Dark Ages," when the ultra-hot universe was opaque.

The Dark Ages began to end about 500 million years after the Big Bang, when so-called reionization occurred as the first stars and galaxies lit up. Galaxies so distant, however, have been nearly impossible to find with existing telescopes. Some astronomers believe they see reionized structures within the HUDF image. But not all agree. "Like most cutting-edge science, there's controversy about the results," says Beckwith.

An answer will require detecting even earlier galaxies. While Hubble has done much, it may take the James Webb Space Telescope, due in 2011, to settle the issue.

— FRANK SIETZEN, JR.

MARSIS: shake, rattle, and roll

After a delay of more than a year, European scientists intend to deploy a potentially dangerous antenna on the Mars Express spacecraft now circling Mars. If successful, the instrument using the antenna could map ice and liquid water far below the planet's surface.

The search for subsurface water deposits is highly important. Hints of an active biosphere accumulate while life scientists grow more confident that, in theory, life could survive under a deep-frozen, radiation-scoured surface.

MARTIAN SHIMMY. The ground-probing radar on Mars Express uses two whiplike antennae. Mission controllers worry that deploying them will shake the spacecraft. ESA

Called MARSIS (for Mars Advanced Radar for Subsurface and Ionospheric Sounding), the device has a pair of 1-inch-thick (2.5 centimeters), 65-foot-long (20m) fiberglass booms that allows radar beams to penetrate 3 miles (5 km) into the ground.

The antenna was supposed to deploy in April 2004. The booms are spring-loaded into boxes on the spacecraft, and the plan was to unlatch the boxes and let them spring out.

They each weigh only about 2 pounds (1 kg) and are flexible. Shortly before planned deployment, a computer model suggested hinges could buckle and backlash was possible. In extreme cases, the unfolding booms could whip back and strike the spacecraft, potentially damaging its instruments or solar arrays. More sophisticated simulations showed the booms deployed less violently but buckled more easily.

Scientists have little control except to vary the equipment's temperature. But they can select the mission phase when damage would be least costly: If most other instruments have completed their initial surveys, the threat of lost science is diminished.

The new deployment schedule is based on the probe's orbit at Mars. Its path is highly elliptical, with the lowest point over the south pole every 6 hours. As Mars circles the Sun, the probe's orbital plane shifts into the planet's shadow, then out again, over months. This limits the amount of electrical power available for the radar pulses.

Beginning in March 2005, the probe will be in full sunlight again. Most instruments will be near the end of their planned investigations, so the cost of a "bad day in Mars orbit" will be lessened. Yet there is still plenty of lifetime left for a radar survey.

Deployment in spring will come just in time, as another mission (Mars Reconnaisance Orbiter) carrying a similar radar experiment will launch in August 2005. Even if the MARSIS booms damage the probe, the process will prove useful in operating the next radar experiment. **— JAMES OBERG**

Cratered layers

SHEETS OF ROCK. The upper walls of this Martian crater show bedrock with finely layered strata. The crater lies in Lycus Sulci, northwest of Olympus Mons; the layers may be lava flows or volcanic ash. Sunlight falls from the upper right in this image, which spans roughly 1.9 miles (3 km). NASA/JPL/MSSS/IMAGE R17-02753

PLANETARY SCIENCE

More Mars water?

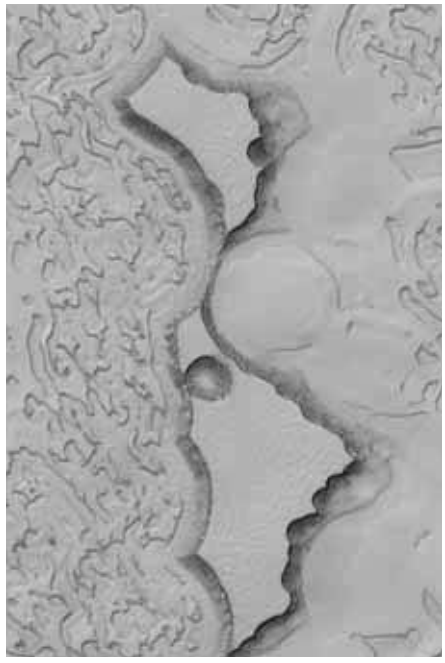
Mars rover Spirit, exploring the Columbia Hills in Gusev Crater, is finding rocks that may show signs of water alteration. Tetl rock (below) is layered horizontally, and scientists aim to find out if the layering is volcanic or sedimentary in nature.

Opportunity has seen signs (polygonal cracks) that some rocks in Endurance Crater were soaked at least a second time after forming underwater.

On Spirit, a steering and brake problem has developed that may limit the rover's mobility. Engineers are trying to find a fix or a work-around. — R. B.

SIGNS OF WATER. The layers in Tetl rock may be due to deposition underwater or by water seeping inside. NASA/JPL/CORNELL

MARS PHOTOJOURNAL



COLD MOUNTAINS. These mesas, lying at a latitude of 86.5° south, form part of Mars' south polar cap. They consist of solid carbon-dioxide ice that is slowly evaporating. The mesa scarps retreat about 10 feet (3 meters) each martian summer. This Mars Global Surveyor image covers an area about 1.2 miles (2 km) across. NASA/JPL/MSSS/IMAGE E12-00825

PLANETARY SCIENCE

Roving into martian spring

Both Mars rovers revived after a brief midwinter nap. The plan for Opportunity is to examine Burns Cliff, then leave Endurance Crater for Victoria Crater, five times larger and lying 3.5 miles (5.7 km) south. On the way, Opportunity will stop where its heat shield landed. **— R. B.**

BRAIN ROCK. Wopmay, a 3-foot-long (1m) boulder in front of Burns Cliff, appears much altered by water. NASA/JPL/CORNELL

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The year in astronomy

For those interested in probing deep space, exploring new worlds, or witnessing rare sky events, 2004 was a banner year.

/// BY FRANCIS REDDY ///

IN THE PAST YEAR, robotic spacecraft landed on Mars, slid into orbit around Saturn, whizzed past a comet, and brought solar samples to Earth. Millions watched as Venus glided across the Sun for the first time in 122 years. Discoveries of planets around other stars — plus an unusual icy body found orbiting our own Sun — ignited imaginations around the world. And astronomers using the Hubble Space Telescope imaged galaxies less than 1 billion years old, heralding a new era in the study of the early universe.

For fans of space science, 2004 was made to order. *Astronomy*'s editors conferred and ranked the most significant space-science stories of the last 12 months. January is the customary month for looking back, so here is our countdown — what would be yours? — through the year's top stories.

#10 Halloween's solar storms

THE REMARKABLE SOLAR ACTIVITY of late 2003 has become legend among space scientists, and it continued to play into 2004. On April 28, a multi-billion-ton cloud of plasma launched from the Sun during October and November passed the Voyager 2 spacecraft, more than 73 AU away, or 73 times Earth's distance from the Sun. (Voyager 1, more than 91 AU away, detected nothing.) Scientists hope the plasma will generate radio waves when it interacts with the heliopause — the boundary between our solar system and interstellar space — and that both Voyagers will detect them.

Between October 19 and November 7, 2003, the Sun blasted three of the most powerful solar flares since at least 1976 and triggered one of the most intense geomagnetic storms since 1932. By the time this activity peaked in late October, scientists were already calling the episode the "Halloween storms."

The activity began when the largest and most complex sunspot groups in more than a decade appeared on the Sun. The largest group — named Active Region 10486 — fired off two record flares and hurled billion-ton coronal mass ejections, or CMEs, toward Earth, which triggered vivid auroral displays as far south as Florida. Then, on November 4, it produced a singular eruption. Scientists couldn't classify the flare precisely because its radiation swamped satellite sensors, but they estimate it topped out at X28 on their intensity scale, which would make it the most powerful flare ever recorded. Recent analysis of how Earth's atmosphere reacted to the flare suggests it ranks even higher.

The storms were by no means the worst possible, experts say, yet they destroyed two multi-million-dollar Japanese satellites, damaged instruments on several spacecraft — including NASA's Mars Odyssey and Advanced Composition Explorer — and caused a blackout in Malmö, Sweden.

#9 To catch a piece of the Sun

THE GENESIS SPACECRAFT spent 2½ years in space. Its mission: to collect particles of the Sun and return them to the U.S. Army Proving Ground in Dugway, Utah, southwest of Salt Lake City, in 2004.

Scientists sought pristine subatomic particles from the solar wind, the stream of ions that continually issues from our Sun. Although the Sun generates energy deep in its core, where it transforms hydrogen into helium through nuclear fusion, its outer layers have been essentially unaltered since its birth. So an accurate census of the solar wind's chemical composition should reflect the composition of the nebula that formed our solar system. The spacecraft caught billions of subatomic particles in metal foil and in 275 coaster-size, hexagonal wafers. Scientists expected Genesis to return just 0.4 microgram of unadulterated Sun.

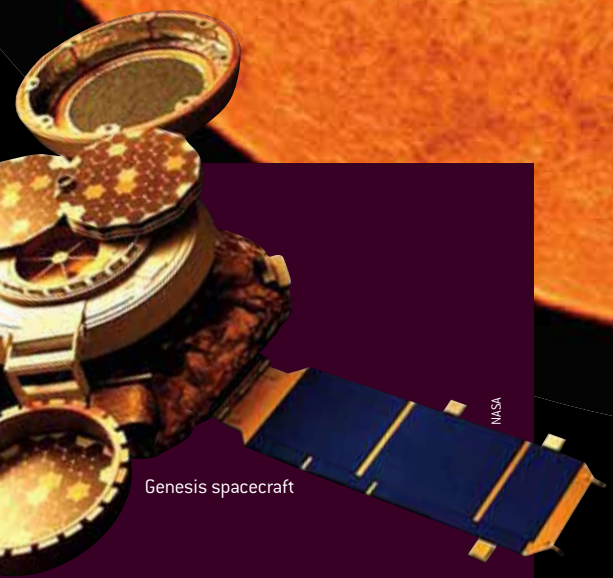
On September 8, the Genesis capsule was to enter the atmosphere and float toward Earth on a parafoil, then waiting helicopters would snatch it in midair. Instead, the capsule hit the desert at 193 mph (310 km/h). Early findings indicate a badly engineered deceleration sensor was at fault.

While soil contamination from the playa where the spacecraft landed still complicates recovery of science from the $264-million mission, scientists quickly recovered three undamaged "concentrator

TROLLING FOR SOLAR PARTICLES, the Genesis spacecraft (above right) exposed foil collectors to the solar wind. But its landing went awry (right) when the craft's parafoil failed to open on reentry and the spacecraft hit the ground at high speed. NASA/JPL

EXPLOSIONS ON THE SUN (above) in late 2003 sent shock waves that reached the edge of the planetary system. BBSO

WIDESPREAD AURORAE, such as this imaged in Oklahoma (below), were one result of the Halloween storms. DAVID EWOLDT



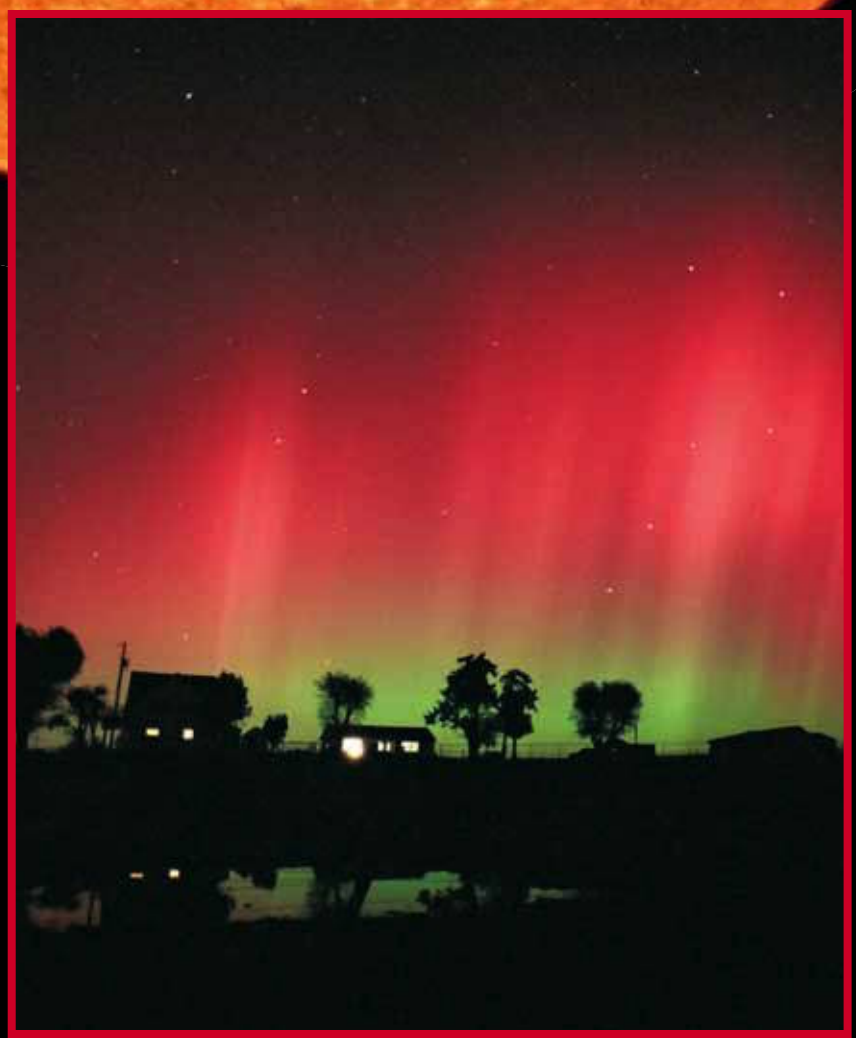
NASA

Genesis spacecraft

targets," many nearly complete hexagons, and much of the foil.

"If you had told me September 8 that we would be ready to move Genesis samples to Houston within the month, I would have replied, 'no way,'" says Don Sweetnam, mission project manager at NASA's Jet Propulsion Laboratory (JPL), in Pasadena, California.

Lessons learned from the Genesis crash will be applied to all future sample-return missions, two of which are in progress. In 2006, NASA's Stardust (see No. 7) will deliver comet dust to the same Utah landing site, and a Japanese probe named Hayabusa is scheduled to arrive at asteroid Itokawa this year and return samples in 2007.

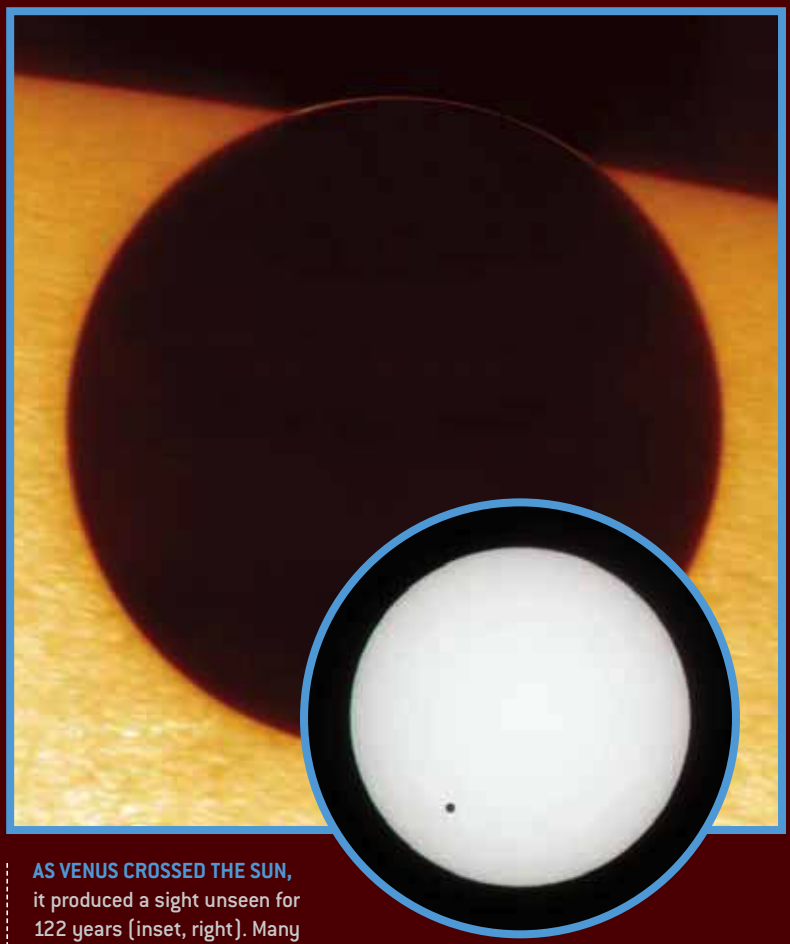


#8 Transit of Venus

UNTIL JUNE 8, NO ONE LIVING had seen Venus in transit. On that day, though, millions watched the planet slip slowly across the Sun's face on television or web sites and lined up for first-hand telescope views at museums, planetaria, and science centers around two-thirds of the globe.

Skywatchers in Asia, Australia, and on Pacific islands were the first to see Venus nudge its way onto the Sun, and observers in the Midwestern United States were among the last to see it leave. The famous black-drop effect occurred, faintly blurring the planet's edge as it contacted the Sun's limb, but observers noted the effect was hardly as prominent as sketches from previous transits suggest.

Although the transit was neither as moving nor as beautiful as a total solar eclipse, many found it nearly as striking. Venus became substantial, a hard-edged, solid black dot — not just the brilliant point of the morning or evening star. It was a planet in its own right, showing its true size and shape as it slipped between Earth and the Sun. To quote Englishman Jeremiah Horrocks, now celebrated as the first to observe a Venus transit in 1639, it was an "agreeable spectacle" indeed.



AS VENUS CROSSED THE SUN, it produced a sight unseen for 122 years (inset, right). Many observers were struck by how big Venus appeared. The Swedish 1-Meter Telescope (big image) captured the thin, bright line of sunlight filtering through Venus's atmosphere. ROYAL SWEDISH ACADEMY OF SCIENCES; INSET: R. ROGERS

NASA'S STARDUST MISSION aims to return dust samples from Comet 81P/Wild 2 (pronounced Vilt, named after its Swiss discoverer). The samples won't arrive at Earth until 2006, but images from the spacecraft's 14,000 mph (22,000 km/h) flyby gave scientists the most detailed and surprising views of a comet yet.

"We thought Comet Wild 2 would be like a dirty, black, fluffy snowball," says Donald Brownlee, a planetary scientist at the University of Washington and the mission's principal investigator. Stardust gathered 72 images January 2, 2004, when it flew within 146 miles (236 km) of Wild 2. The images show pinnacles 330 feet (100 meters) tall and craters more than 490 feet (150m) deep. Such a diverse landscape, argues Brownlee, calls for a surface that's surprisingly strong and cohesive.

Wild 2 has not resided long in the inner solar system. In September 1974, it passed close to Jupiter, and the encounter forced the comet into a much smaller orbit. So scientists believe its samples will be representative of distant comets that spend little time near the Sun.

Stardust flew through at least a dozen dust jets, three of which blasted the spacecraft with more than a million

CASSINI'S ARRIVAL at Saturn began a 4-year tour of the ringed planet. Early results include never-before-seen details of the rings. NASA/ISS

#7 Comet encounter

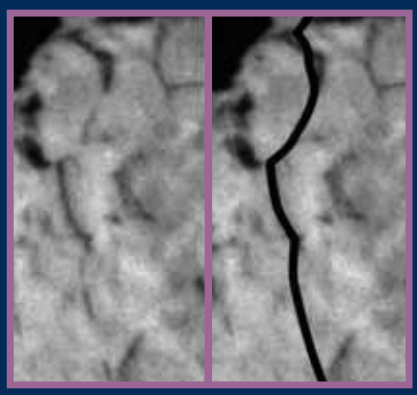
particles each second. "Stardust was absolutely pummeled," says Thomas Duxbury, mission project manager at JPL. Twelve particles, some larger than a bullet, penetrated the top layer of the craft's protective shield.

During the flyby, Stardust captured dust particles ranging in size from 1 micrometer — or about 1/50 the width of a human hair — to about 100 micrometers in tennis-racket-size collectors

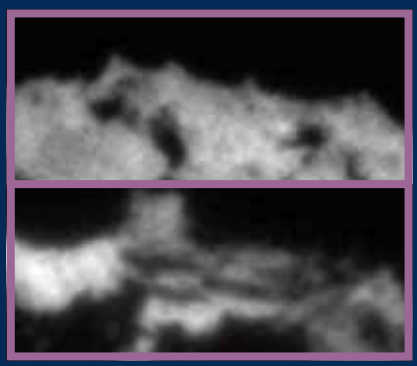
On January 15, 2006, the capsule will land by parachute at the the same landing site where Genesis slammed down.

"We've updated our contingency plan to make sure we have everything we need on-site in the event of a crash," says Brownlee. "We designed our sample canister so that it will have to be cut open if damaged, even in an impact."

THE NUCLEUS OF COMET WILD 2, imaged by Stardust as it flew past, shows enigmatic bumps and depressions in this composite image (above). Scientists are still working to understand the processes behind these surface features. Surrounding the nucleus like a halo are the main, bright jets. NASA/JPL



DEPRESSIONS AND CLIFFS suggest the surface has been eroded by impacts and heating. The line traces a scarp. NASA/JPL



WEIRD PINNACLES and peaks, seen in profile on the limb of the nucleus, stand high above the comet's surface. NASA/JPL

#6 Cassini at Saturn

THE MOON IAPETUS has one side as white as snow and the other is as black as coal. NASA/ISS

THE CASSINI-HUYGENS spacecraft braked into orbit around the ringed planet June 30.

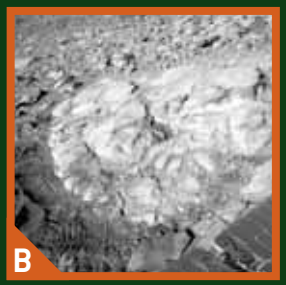
"What you're seeing in press releases is just a skimming of some of the cream," notes project scientist Dennis Matson of NASA's JPL. Cassini scientists are too busy operating the spacecraft to interpret fully the rich load of data they've received.

Saturn's moon Phoebe, which Cassini passed as it entered the saturnian system, gave scientists the first of many surprises. "We all knew for sure that Phoebe was just a dull rock," Matson jokes. Instead, "you've got very interesting topography, you've got patches of water ice, you've got places where there's CO_2 on the surface," as well as areas coated with material so far unidentified.

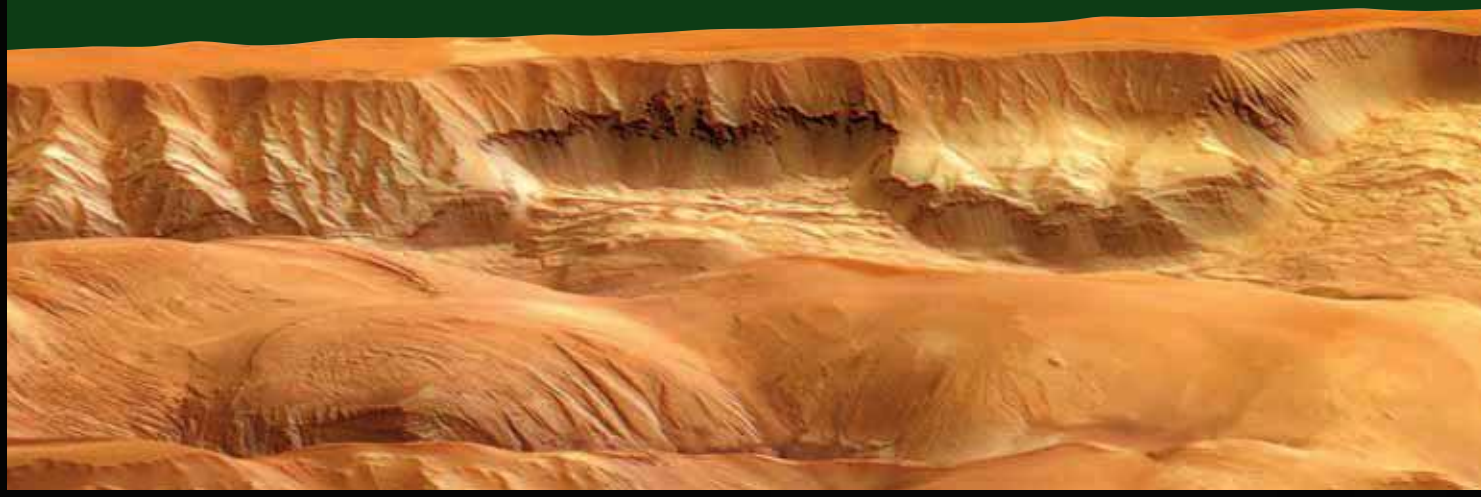
Cassini found that Saturn's radiation belts extend closer to the planet than previously suspected. "We always thought the rings would pretty well absorb everything," Matson says. Radiation belts are regions of energetic electrons and ions trapped in a planet's magnetic field. Cassini detected neutral gas atoms accelerated by collisions with fast-moving ions, allowing scientists to map the new belt. It extends from just above Saturn's cloud tops all the way to the inner edge of the D ring.

Titan, Saturn's largest moon, glows day and night in the near-infrared. By day, sunlight makes the methane fluoresce, while on the moon's night side, carbon monoxide shines at different wavelengths. Cassini's most-awaited encounter occurs January 14, when the Huygens probe drops into Titan's atmosphere and, perhaps, sends back data from its surface.

BACKGROUND IMAGE: NASA AND E. KARKOSCHKA (UNIVERSITY OF ARIZONA)



OUR BEST-EVER LOOKS at Mars came with the arrival of two landers and an orbiter to join two other orbiters. Mars rover Spirit searched for evidence of water in Gusev Crater's Columbia Hills. It gained distant vistas (A) and examined outcrops such as Clovis (B). Opportunity, Spirit's twin, found layers of water-laid sediments exposed in and near Endurance Crater (C). Europe's Mars Express began mapping the planet in stereo, yielding perspective views such as this showing Ophir Chasma (below). NASA, ESA



#4 Hubble's troubles

ON JANUARY 16, 2004, NASA Administrator Sean O'Keefe canceled the final space-shuttle mission to service the Hubble Space Telescope. Launched in 1990, Hubble received corrective optics, new instruments, and various upgrades in four previous shuttle flights. But after the February 2003 Columbia disaster, O'Keefe deemed another shuttle servicing mission too risky.

"The announcement ... which we refer to around here as Black Friday, was pretty devastating," says Steven Beckwith, director of the Space Telescope Science Institute (STScI).

Instruments that would extend Hubble's scientific capabilities have already been built but can't be installed without a servicing mission. And experts predict the telescope will fail by 2009 without replacement gyroscopes and batteries. "If the batteries go, the whole satellite basically shuts down, and we don't think we can recover it with servicing," Beckwith notes. In early August, as if to underscore the urgency, an instrument involved in nearly a third of HST's science unexpectedly fell silent.

In mid-August, on a visit to NASA's Goddard Space Flight Center, O'Keefe endorsed a robotic mission to save the telescope. Engineers showed that a two-armed robot named Dextre, designed for use on the International Space Station, could install new instruments on Hubble. Because Dextre is qualified for space flight already, engineers believe they can fly a mission before Hubble's time runs out.

Beckwith remains cautiously optimistic. "Hubble is the original comeback kid," he says, "and I think it can come back again."

Francis Reddy *is an associate editor of* Astronomy.

#5 The earthlings' assault on Mars

(When Astronomy *went to press, both rovers were still active. Despite a few age-related problems, mainly involving Spirit, both rovers appear fit enough to continue exploring Mars for several months more.)*

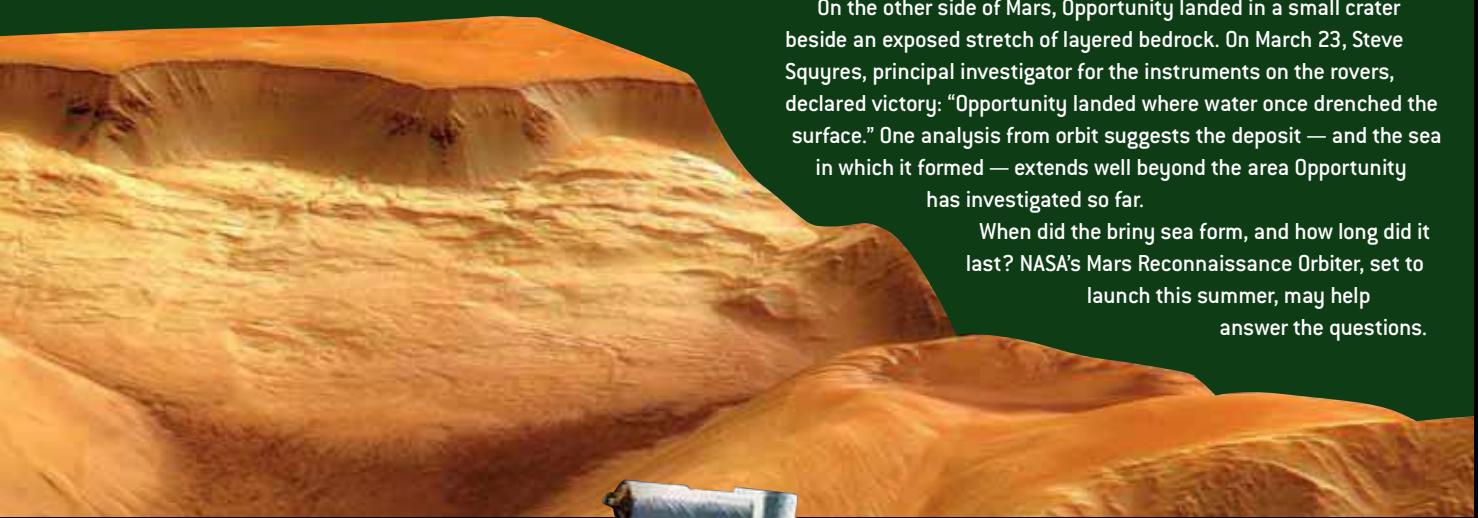
AN ARMADA OF SPACECRAFT arrived at Mars in late 2003 and early 2004. First came the European Space Agency's Mars Express orbiter and the ill-fated Beagle 2 lander piggybacked on it. Then, in January, NASA's two golf-cart-size Mars Exploration Rovers, Spirit and Opportunity, tumbled onto opposite sides of the Red Planet. "This was the first landed mission with significant mobility that could really do field geology, thoroughly characterizing two different landing sites," says Joy Crisp, rover project scientist at JPL.

Designed to last 90 martian days, or sols, the rover missions have been extended twice. Spirit has a bum wheel that complicates navigation, and a balky brake, but the problems haven't kept the rover from tackling an ascent of the Columbia Hills after a 2.2-mile (3.5 km) trek across Gusev Crater. "With these rovers — wow, we're seeing entirely new vistas," Crisp says. "I feel like I'd hiked up there."

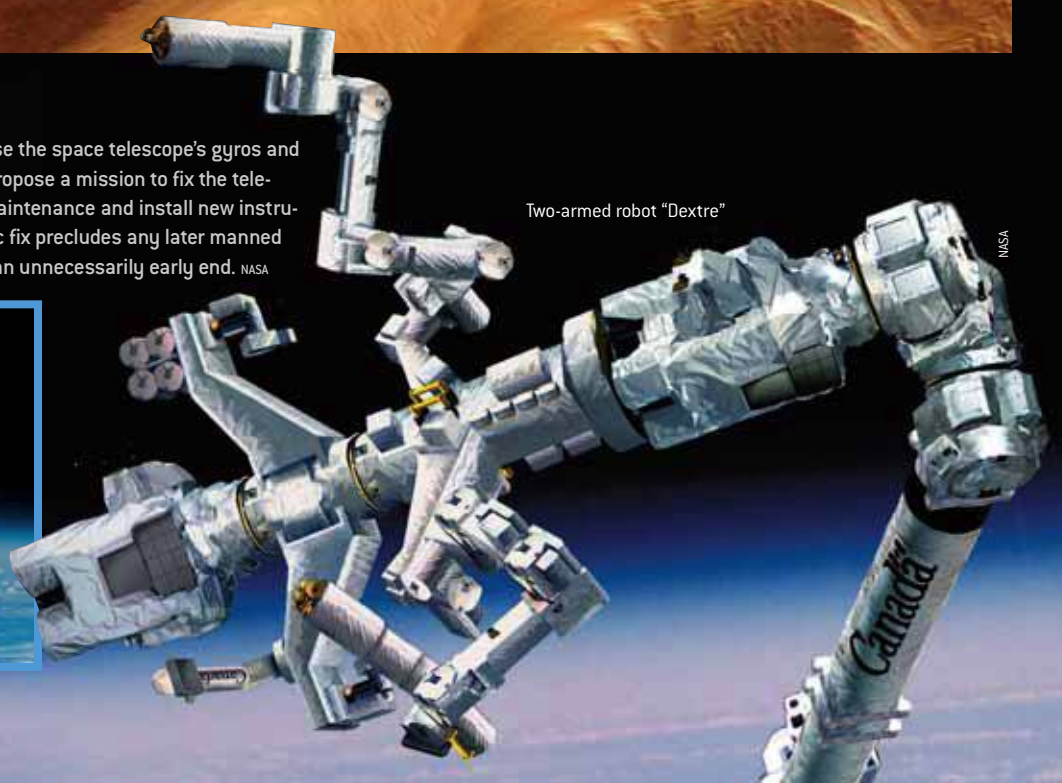
Both rovers found evidence of past water on Mars, but Spirit had to work for it. "We drove a long way at Gusev, and the clues there are more puzzling to us," Crisp says. Olivine, a mineral found near the landing site, breaks down in the presence of water, so its presence suggests the landing site has long been dry. But once in the hills, Spirit found an outcrop, dubbed Clovis, with elevated levels of bromine, chlorine, and sulfur — all suggesting water had altered the rock.

On the other side of Mars, Opportunity landed in a small crater beside an exposed stretch of layered bedrock. On March 23, Steve Squyres, principal investigator for the instruments on the rovers, declared victory: "Opportunity landed where water once drenched the surface." One analysis from orbit suggests the deposit — and the sea in which it formed — extends well beyond the area Opportunity has investigated so far.

When did the briny sea form, and how long did it last? NASA's Mars Reconnaissance Orbiter, set to launch this summer, may help answer the questions.



FIXING HUBBLE is a top priority because the space telescope's gyros and batteries are failing. NASA engineers propose a mission to fix the telescope using a robot to carry out the maintenance and install new instruments. Critics, however, say the robotic fix precludes any later manned mission and dooms the spacecraft to an unnecessarily early end. NASA



Two-armed robot "Dextre"

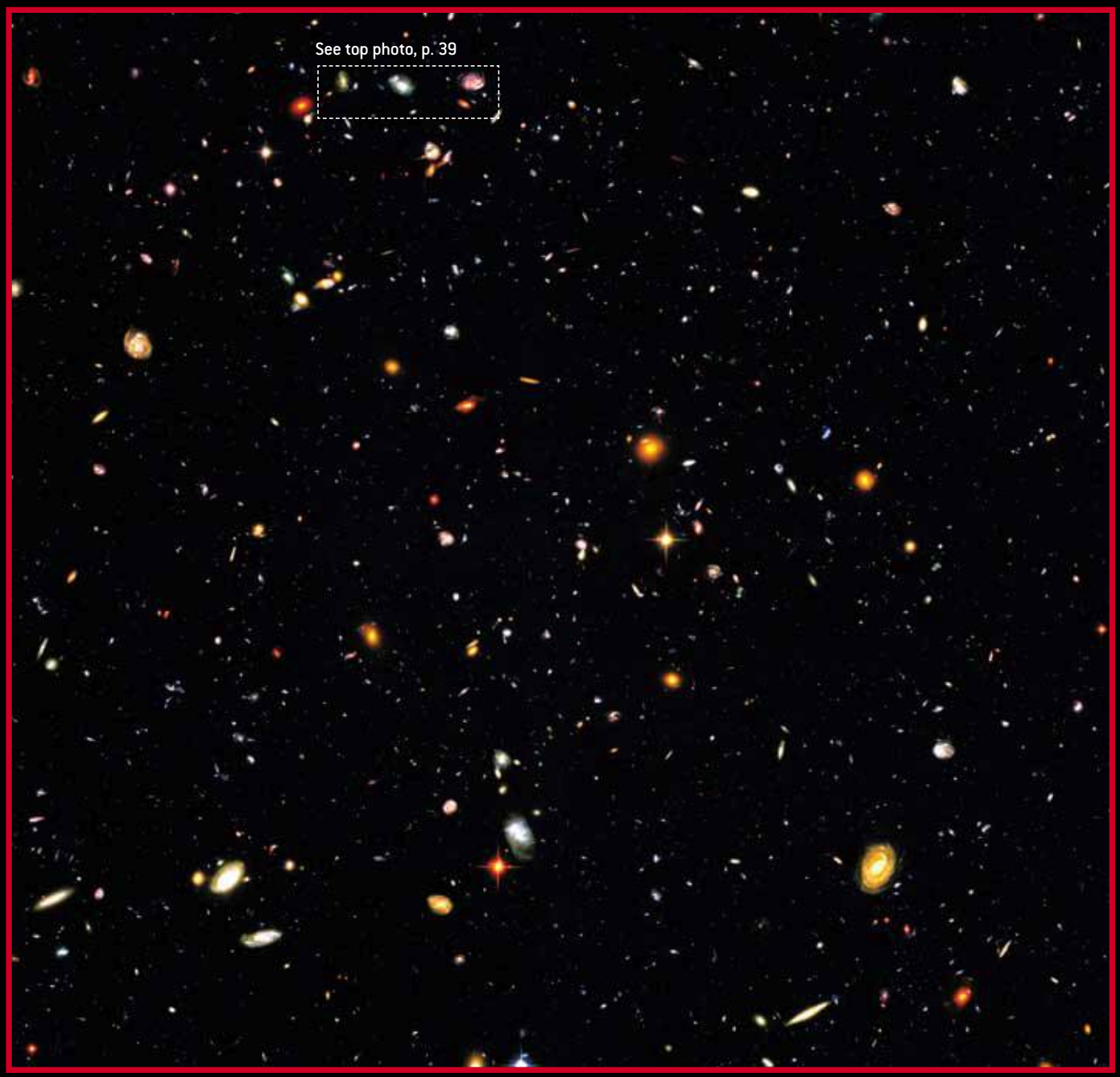
NASA

#3 Hubble's Ultra Deep Field

ON MARCH 9, 2004, STScI astronomers unveiled a million-second-long exposure of a tiny patch of sky. Within 48 hours, astronomers circulated the first science paper using the data. Called the Hubble Ultra Deep Field (HUDF), the image reveals the first galaxies to emerge from the so-called Dark Ages, the time shortly after the Big Bang when the first stars reheated the cold, dark universe.

"Hubble takes us to within a stone's throw of the Big Bang itself," says STScI's Massimo Stiavelli, project leader for the HUDF. The view is actually a combination of two separate images taken by the Advanced Camera for Surveys (ACS) and the Near Infrared Camera and Multi-Object Spectrometer on Hubble. The image lets astronomers study galaxies that existed between 400 and 800 million years after the Big Bang.

There is no question the HUDF galaxies are incredibly remote, but some astronomers disagree that the HUDF


See top photo, p. 39

GOING VERY DEEP, the Hubble Space Telescope made the longest exposure it had ever done — lasting 11.5 days and gathered over many orbits of Earth — to capture young galaxies (see inset at top right) as they existed soon after the Big Bang. NASA/STScI

shows the first galaxies. "I think that can be resolved with deep infrared observations to see if there's some other population we don't see, and if there's not, I think that will settle it," explains STScI director Steven Beckwith. But it will likely take the new Wide-Field Camera 3 on Hubble — plus a servicing mission to install it — to do the job right. In any case, the HUDF will remain the deepest-ever optical and infrared view of the universe until the James Webb Space Telescope, a joint project between NASA and ESA, begins operations in 2011.

WHEN ASTRONOMERS SCRUTINIZE the Hubble Ultra Deep Field image, they find galaxies that resemble today's galaxies only partly. Astronomers hope eventually to write a history of galaxy formation from the Big Bang until now. NASA/STScI

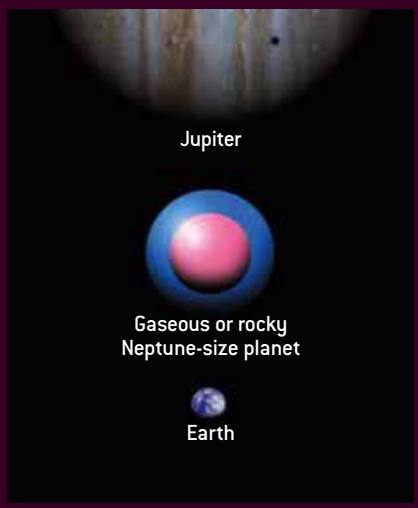
#2 Exoplanets aplenty

OF THE EXTRASOLAR planets found in 2004, most significant were the "exo-Neptunes." These objects are far smaller than any previously detected planet around a Sun-like star. Some 135 exoplanets have been securely identified, and while the goal of finding planets like Earth around stars like our Sun has yet to be realized, the exo-Neptunes bring astronomers one step closer.

The find "puts us in that transition region where we can't quite see the earthlike planets yet, but we're seeing their big brothers," says Paul Butler of the Carnegie Institution of Washington. Butler and colleagues found a planet weighing 25 Earth masses around the red dwarf star Gliese 436. It revolves around its star in only 2.64 Earth days from only 0.028 AU away.

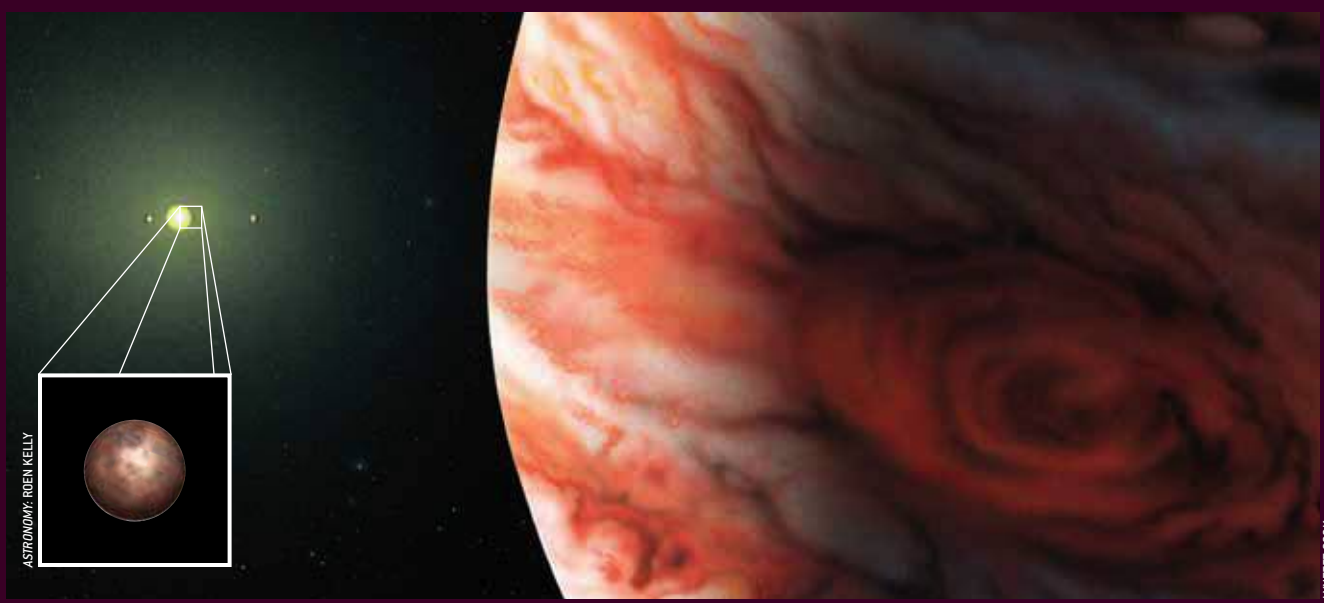
Another new planet was discovered around 55 Cancri, already known to have three others, making this the first four-planet system identified so far. The new world orbits its sun every 2.81 days, lies just 0.038 AU away from its star, and has nearly the same mass as Neptune, or about 18 times that of Earth.

A third team, led by Michel Mayor of Switzerland's Geneva Observatory, reported the least massive planet yet: a 14-Earth-mass "exo-Uranus." The planet orbits Mu (μ) Arae, a Sun-like star about 50 light-years away, every 9.6 days at a distance of 0.09 AU.



ASTRONOMERS HAVE FOUND exoplanets that bridge the mass gap between planets such as Jupiter and Earth. NASA/JPL/CALTECH

THE FIRST FOUR-PLANET SYSTEM known, 55 Cancri has an "exo-Neptune" orbiting close to the star (see inset left).



ASTRONOMY: ROEN KELLY

LYNETTE COOK

#1 Discovery of Sedna

IN MARCH, astronomers exploring the cold, dark recesses of the outer solar system found something unexpected.

"Not in our wildest dreams was this object going to be out there," says codiscoverer Mike Brown, an astronomer at the California Institute of Technology in Pasadena. "It's tremendously exciting."

What Brown and colleagues Chad Trujillo (Gemini Observatory) and David Rabinowitz (Yale University) found is the solar system's most distant object, an icy body perhaps 75 percent the size of Pluto. It never comes closer to the Sun than 76 AU, and it spends most of its 10,500-year orbit at much greater distances, as much as 480 AU. Its discoverers have named it Sedna, after an Inuit undersea goddess.

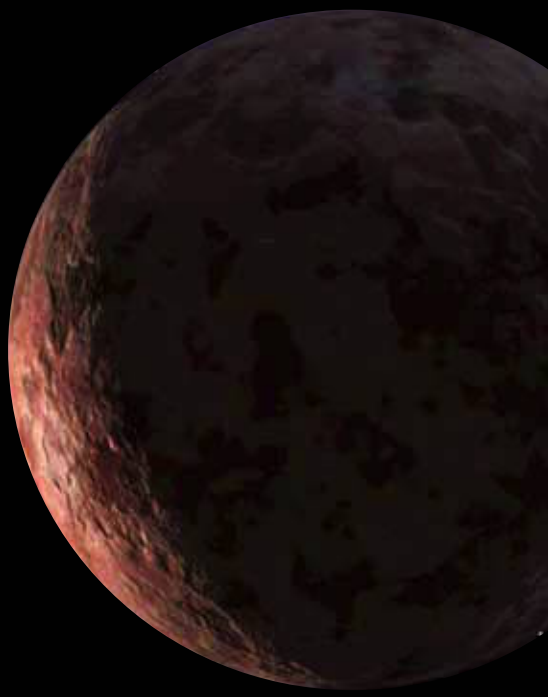
"It took me a while to realize this, but the discovery of Sedna is essentially equivalent in importance to the discovery of Pluto," says Brown. No one knew it when Pluto was discovered in 1930, of course, but it was the first Kuiper Belt object discovered — the first known member of a population of objects that could teach astronomers about how our solar system formed.

The same is true for Sedna, Brown argues. It lies well beyond the Kuiper Belt, and it's likely to be the first of a new population. "If you look at Sedna's orbit, it never gets closer than 76 AU, so it's never anywhere even remotely close to Neptune," Brown says. This means it can't be a "scattered disk" object, one of many Kuiper Belt bodies flung into unusual orbits by close encounters with Neptune. Far from any major planet, yet close enough to be held firmly by the Sun, Sedna seems to be "in the one place in the solar system where you put things and they stay there forever."

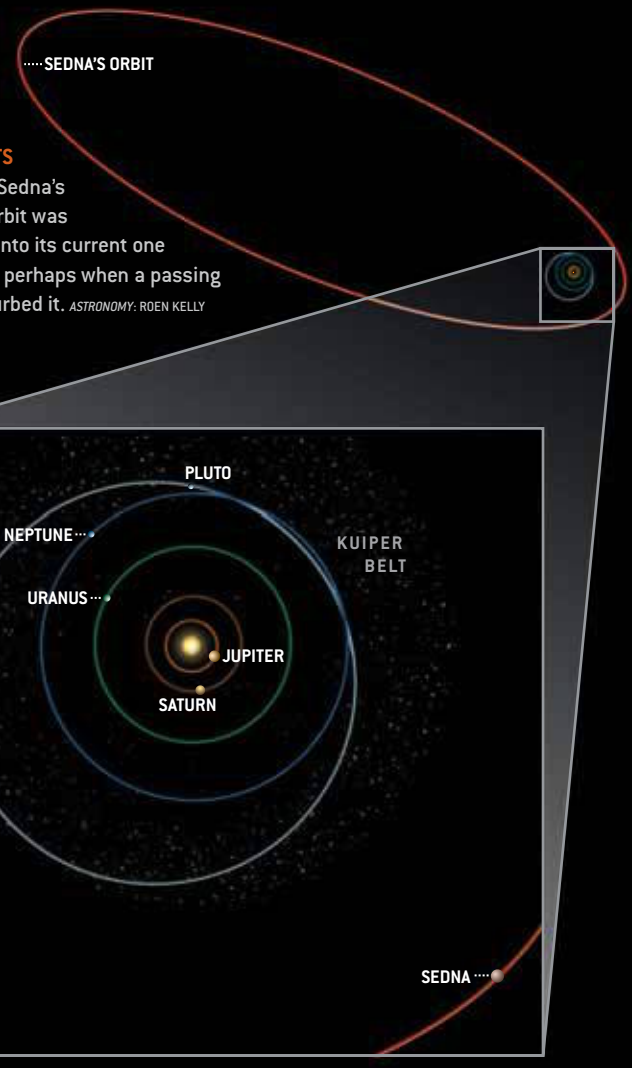
Computer simulations suggest only a passing star was able to emplace Sedna. But if the star wanders by more than 100 million years after the Sun forms, its passage so warps the Oort Cloud that most of the Sun's comets escape. This leads Brown and others to suggest the solar system formed in a cluster of stars, and that a close stellar pass early in our solar system's history put Sedna in its place.

It's also possible that a large unknown planet lurks in the dark, shaking up Sedna and its relatives the way Neptune stirs up the scattered disk. "When we find 10 of these, maybe even fewer, the answer will be obvious," Brown insists. "When we find 20 of these, and if ... the Sun formed in a cluster, I will be able to tell you so many details about what the cluster was like that it'll blow your mind." A

For more information on many of these discoveries, see www.astronomy.com/toc



THE FARTHEST-KNOWN MEMBER of the solar system is the icy planetesimal Sedna. Even at its closest, Sedna lies 76 times farther from the Sun than Earth. NASA



SCIENTISTS SUSPECT Sedna's original orbit was changed into its current one ages ago, perhaps when a passing star perturbed it. *ASTRONOMY:* ROEN KELLY

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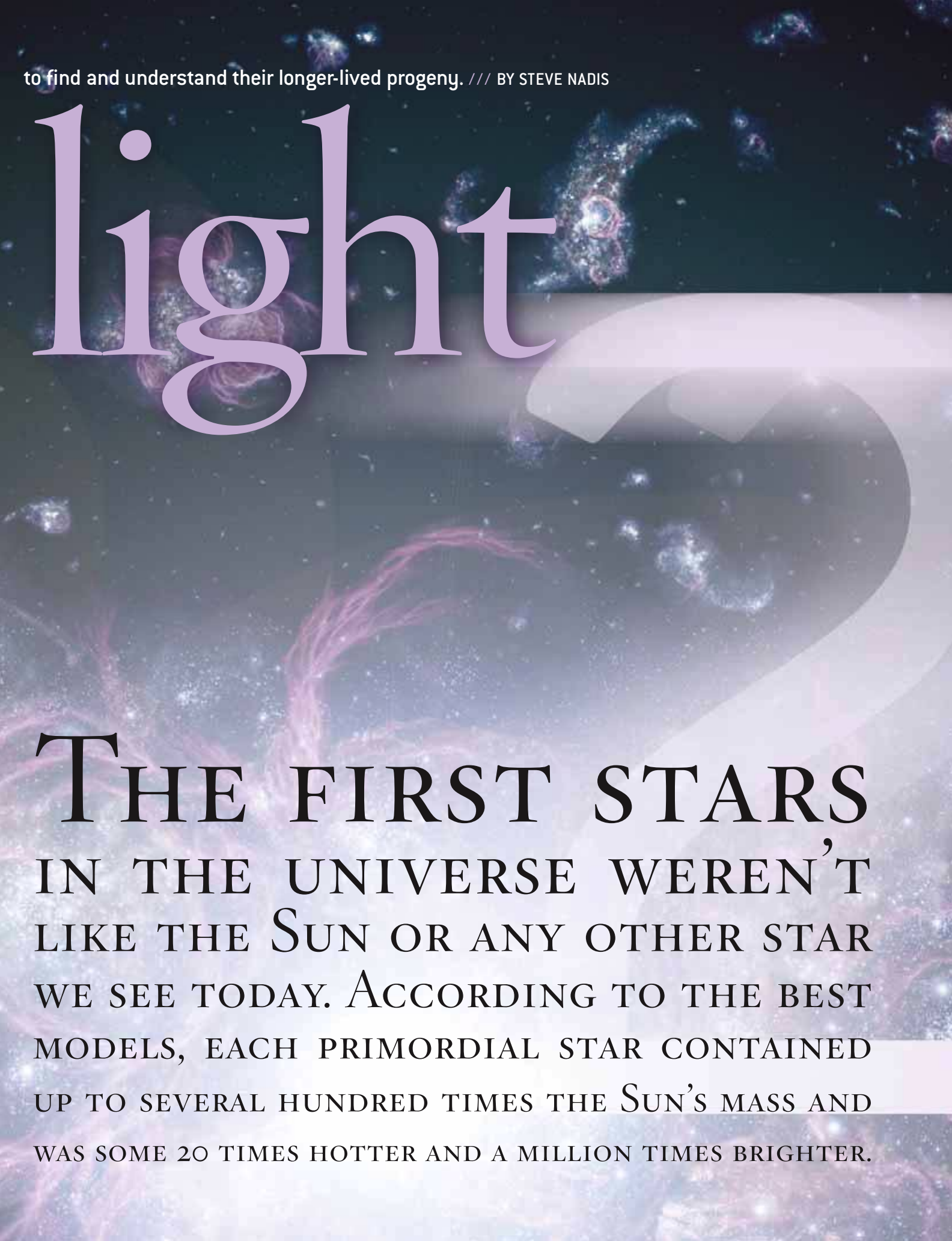
The first generation of stars lived fast and died young. Now, astronomers have launched an assault

{ COSMOLOGY }

Second

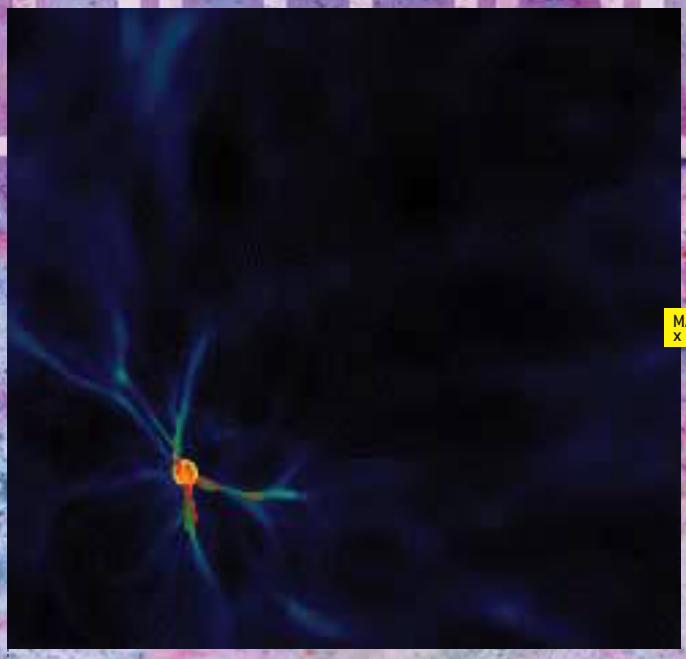
THE DARK AGES of the early universe ended with the rise of the first stars. These massive objects quickly went supernova, seeding the cosmos with elements that allowed stars similar to the Sun to form. ADOLF SCHALLER FOR STScI



to find and understand their longer-lived progeny. /// BY STEVE NADIS

light

The first stars in the universe weren't like the Sun or any other star we see today. According to the best models, each primordial star contained up to several hundred times the Sun's mass and was some 20 times hotter and a million times brighter.



THE FIRST STARS FORMED within a few hundred million years of the Big Bang. This simulation shows how temperature changes as we zoom in on one such star. In the first step, we see a volume 18,000 light-years wide containing a 1-million-solar-mass object. TOM ABEL, GREG BRYAN, AND MICHAEL NORMAN

AS WE ZOOM IN by a factor of 10, the million-solar-mass object starts to show detail. The highest temperatures (in yellow) arise as cold gas falls in from the outside. The object's internal gas pressure slows the infalling gas, converting kinetic energy to heat. The first star hides in the center.

Born in a cold, neutral, and pristine environment from pure hydrogen and helium left over from the Big Bang, these so-called Population III stars irrevocably changed the space around them. Their searing surfaces spewed a steady stream of ultraviolet light. Meanwhile, deep inside, their nuclear furnaces forged elements heavier than helium — "metals" in astronomical parlance.

After shining only a few million years, they self-destructed in dramatic fashion. Their terminal supernova blasts released the metals, along with intense radiation. "The next generation of stars, and all the others to follow, were born in a different universe — hot, ionized, low-density, and contaminated with metals," notes Piero Madau, an astrophysicist at the University of California, Santa Cruz. "It was like a second beginning."

The second generation of stars, called Population II, are the true ancestors of the Sun: They're roughly comparable in mass and, like the Sun, were built from ingredients that included some metals, albeit in modest quantities. The presence of metals enabled low-mass stars — objects that could survive billions, rather than just millions, of years — to form. Eventually, they dominated the stellar population.

Without metals like iron, rocky planets never could have formed around stars, and life as we know it would not have taken root. The transition from a metal-free to metal-rich universe, and the attendant shift from Population III to Population II stars, "set the stage for the long cosmic evolution that eventually led to life and intelligent beings like us," claims Volker Bromm of the University of Texas.

Inquiries about second-generation stars, and the generations they spawned, are not confined to the realm of metaphysics. To the contrary, astronomers hope to see these relics in the far reaches of our galaxy. In fact, a long list of intriguing candidates exists. The payoff for finding a second-generation star would be considerable because it would yield vital clues about the early universe and the first objects in it.

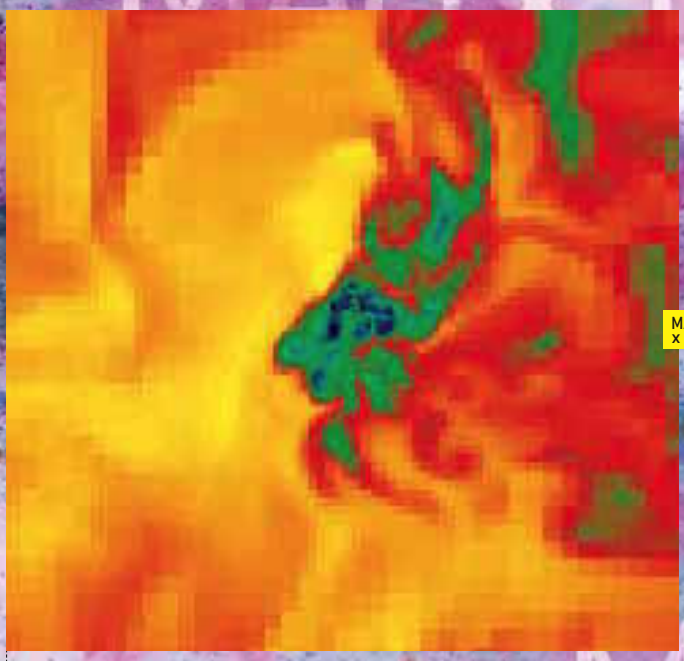
Nevertheless, given our current observational capabilities, many aspects of the early universe remain shrouded in mystery. That's why some of the best views today can be found on computer screens of various practitioners in the "early star" field. The supercomputer simulations run by Tom Abel of Pennsylvania State University and his colleagues, for example, show something that no telescope has yet seen — primordial clouds of hydrogen and helium coalescing to form the first stars roughly 100 million years after the Big Bang.

The fate of these behemoths, ranging from 30 to 300 suns, would depend on their mass. A star containing between 140 and 260 solar masses would come to a particularly violent end called a pair-instability supernova (PISN). Unlike the supernovae we observe today, which merely expel a star's outer envelope, a PISN destroyed the entire star, leaving no vestige behind. In the process, all the heavy elements created from nuclear fusion during the star's life were spread through space. As multiple stars blew up in this manner, says Bromm, "the universe was transformed very quickly."

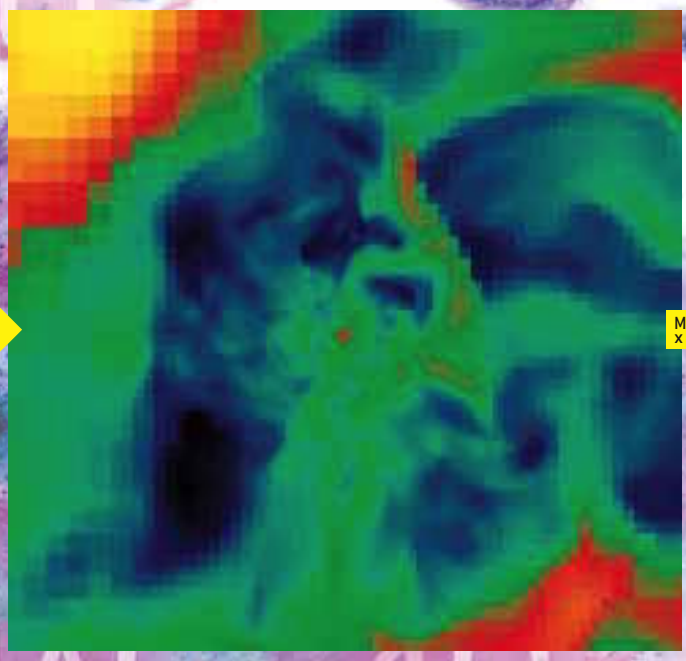
Bromm, along with Harvard colleague Lars Hernquist and Naoki Yoshida of Japan's National Astronomical Observatory, modeled PISN explosions in computer simulations, which showed iron and other elements hurtling through space at tremendous speeds. Three to 5 million years after such a blast, the team concluded, a region one kiloparsec (3,260 light-years) in radius would have been seeded with a substantial amount of metals. This "enrichment" would have occurred, moreover, when the universe was still in its infancy — within 275 million years of the Big Bang.

Harvard cosmologist Abraham Loeb and Steven Furlanetto of the California Institute of Technology devised a mechanism to

Steve Nadis *is a science writer and frequent* Astronomy *contributor who lives in Cambridge, Massachusetts.*



A DENSE INNER REGION (shown in green and blue) measures about 30 light-years across and has a temperature of only about 200 kelvins. It achieves this cold temperature because molecular hydrogen radiates heat. The entire image shows a region 180 light-years across.



THE STAR-FORMING CLOUD comes into view better when we view a region just 18 light-years wide. Nearly all the material is atomic hydrogen and helium, mixed with just 0.1 percent molecular hydrogen. In contrast, present-day star-forming clouds consist almost entirely of molecules.

explain how metals unleashed by the first stars so quickly permeated intergalactic space. They think correlated supernovae in star-forming regions powered "superwinds" — a phenomenon already documented in starburst galaxies — that propelled the enriched material at velocities up to 3,600,000 kilometers per hour. That might be fast enough to exceed the escape velocity of a small galaxy or cluster. It was easier to spread material around in very early times, explains Loeb, because the supernovae from giant stars were roughly 100 times more powerful than supernovae today. Also, the universe was smaller, and galaxies were smaller, so the winds were able to overcome their weaker gravitational pull.

Dispersing metals is important because a gas cloud on the path to stardom can shed heat more efficiently if it contains substances like carbon and oxygen. These molecules cool the gas by absorbing energy and reradiating it — a necessary step for star formation to proceed. The only way stars can form without metals is when they get big enough so the inward pull of gravity can overcome the outward pressure of the hot gas. Lower-mass stars can form, however, as metallicity goes up.

A few molecules make a big difference

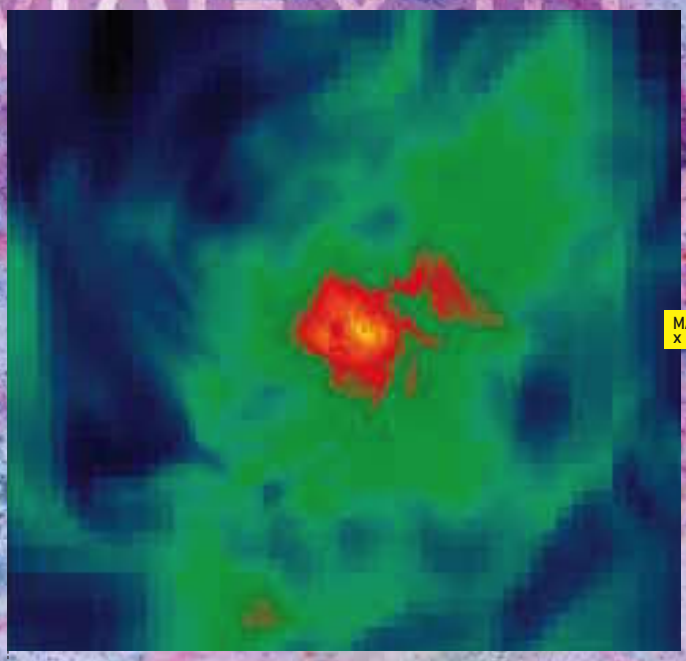
What level of metals is needed to jump-start the formation process? Bromm and Loeb calculate the "critical metallicity threshold" must be about 0.1 percent of the solar abundance of carbon and oxygen to have a significant impact on cooling. When the concentration of dispersed metals exceeds this value, a new generation of lower-mass stars appears and eventually predominates.

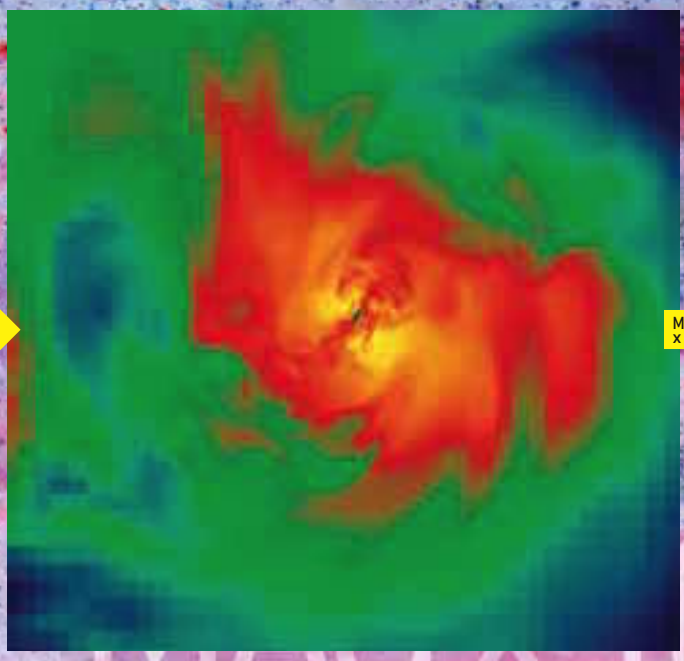
Gas enriched by the first stars served as the building material for second-generation stars. Unfortunately, for astronomers seeking to understand the first generation, these high-mass stars were short-lived. "The elements they created provide one of the few lingering pieces of evidence that can be used to infer their properties," explains Timothy Beers of Michigan State University. In other words, by studying abundance patterns of elements in longer-lived, second-generation stars, we can learn about the environment in which those stars were spawned, and, possibly, divine the mass of their progenitors.

Bromm envisions a hiatus between the first- and second-generation stars because the first supernovae inevitably would heat the surrounding gas to a high temperature. "Since you can't form stars out of hot gas, you need to wait for it to cool down," he says. Based on his simulations, Bromm estimates the pause between generations lasted a few tens of millions of years. Still, he admits it's hard to pin down a precise timetable.

Part of the difficulty stems from the fact that the transition from massive (Population III) stars to more conventional (Population II) stars might not have occurred uniformly during a single epoch. "Second-generation stars did not appear at a particular time because different regions produced first-generation stars at different times owing to density variations," says Loeb. "Rather than following the arrow of time for the entire universe, you're following the history of a particular region." Bromm agrees with that argument but thinks the spread among different regions should have amounted to only a few hundred million years. Hernquist is planning new, large-scale simulations to see whether the transition from Population III to II is synchronized.

It will take at least a year before Hernquist completely analyzes the simulation. Rather than sitting idly in the meantime, observers are pursuing every possible avenue. Astronomers already have spent decades searching for Population III stars. None has been found, which is consistent with current doctrine that says massive objects like that would have blown up long ago. It's still worth looking, claims Abel. "We shouldn't have prejudices about what the universe should be like. If someone does find low-mass, metal-free stars, we'll have to rethink our theories and figure out how to make them."





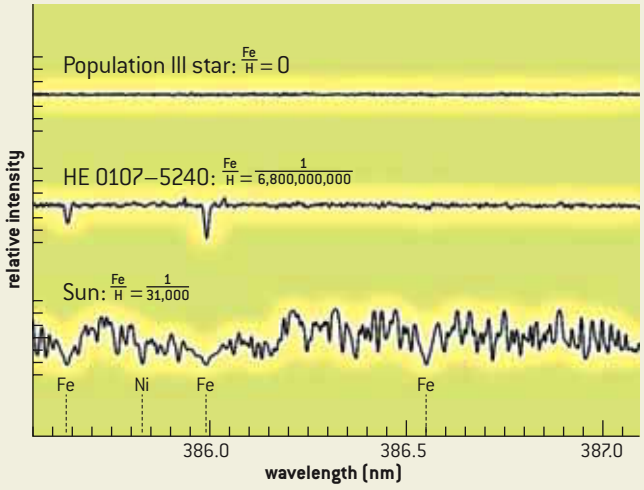
ZOOMING IN by another factor of ten reveals a warmer and denser core, where the real star-forming action is taking place. Interestingly, such primordial clouds were comparable in size to their current counterparts, but their temperatures were some 10 times hotter.

THE RAPID COLLAPSE of the dense core, which contains roughly 200 solar masses of material, heats it further. Note, however, a new feature near the center: an elongated region of lower temperatures (which appears green) that stretches from upper right to lower left.

/// A SECOND-GENERATION STAR?

In 2002, astronomers discovered a star with only about $^{1}/_{100,000}$ the amount of heavy elements found in the Sun — some 20 times less than any star analyzed before. The star, HE 0107–5240, turned up in a survey that looked specifically for stars with a low metal abundance.

The star has 80 percent of the Sun's mass — small enough that it could have survived since the birth of the cosmos. That makes it the best candidate for a second-generation star, born from debris strewn in the supernova of a first-generation star. The star's pedigree isn't guaranteed, however. The spectrum shows surprisingly high amounts of carbon, nitrogen, and oxygen. — *Richard Talcott*



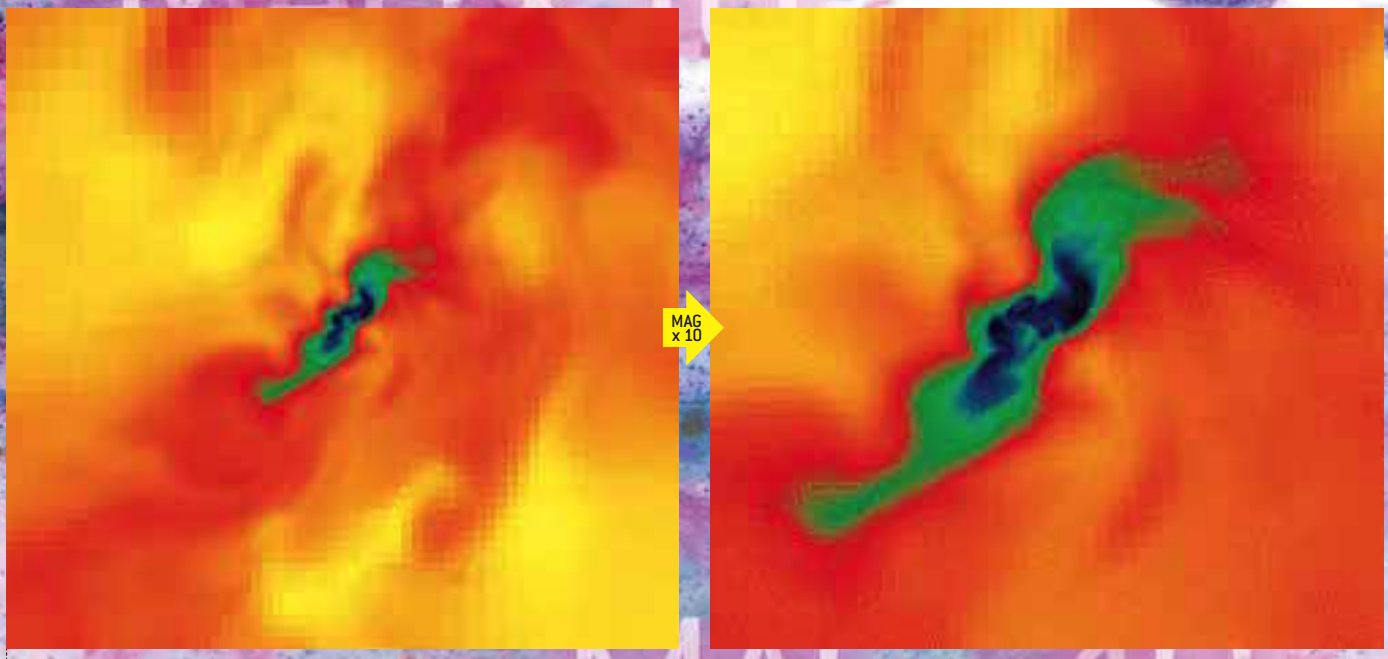
A POPULATION III STAR would have no elements other than hydrogen and helium in its spectrum (top). The metal-poor star HE 0107–5240 shows a trace of iron but little else (middle). Compare that with the Sun, which has 100,000 times as much iron as HE 0107–5240 and plenty of other metals in its spectrum (bottom). ESO

Spotting a second-generation star is more likely because a 0.8-solar-mass star produced shortly after the Big Bang could survive 14 billion years and still exist today. The best place to look is in the galactic halo, on the fringes of the Milky Way, where active star formation has long since ceased. The most successful strategy for identifying metal-poor objects has been to use large telescopes, like the twin Keck instruments in Hawaii and the Very Large Telescope (VLT) in Chile. They can take detailed spectra of outlying stars and look for weak features that indicate low metallicity. Using this approach, says Beers, astronomers have found about 1,000 stars with iron abundances $^{1}/_{100}$ of the Sun's, 100 stars with $^{1}/_{1,000}$ the Sun's iron, 10 stars with $^{1}/_{10,000}$ the Sun's iron, and one lonely star with less than $^{1}/_{100,000}$ the Sun's iron.

That last star, designated HE 0107–5240, was reported in 2002 by Hamburg Observatory astronomer Norbert Christlieb and his colleagues, based on observations with the 8.2-meter VLT. The most iron-poor star known to date, HE 0107–5240 already has been the subject of six papers in the journal *Nature* — unprecedented in the annals of stellar astronomy, according to Beers.

"This is the closest we have ever come to the conditions directly after the Big Bang by studying stars," says Christlieb. He is not alone in considering the 0.8-solar-mass HE 0107–5240 the best candidate for a second-generation star. Yet the object is not without its puzzling features. For one, the measured ratio of carbon to iron is 10,000 times greater than the observed ratio in the Sun — the biggest such "overabundance ratio" ever documented. Relatively large quantities of nitrogen and oxygen also have been detected. Astronomers would like to know where all that carbon, nitrogen, and oxygen came from.

The most convincing explanation for the abundance patterns in HE 0107–5240, says Christlieb, is that the star formed from a gas cloud permeated by debris produced when a 25-solar-mass, first-generation star underwent a normal, type II supernova explosion.



AT A SCALE OF JUST 6 LIGHT-DAYS, the elongated region stands out. It arises because, at this high density, hydrogen atoms collide more frequently, raising the fraction of hydrogen molecules precipitously. Molecules radiate heat more efficiently, so the collapsing cloud cools.

THE COOL CENTRAL REGION contains only about one solar mass of material, but the 200-solar-mass core seen in the previous frames continues to accrete quickly onto this protostar. As the protostar grows more luminous, it will retard this accretion and halt the growth of the universe's first star.

In a model devised by University of Tokyo astronomers Hideyuki Umeda and Ken'ichi Nomoto, heavy elements like iron would have been retained in the core of the parent Population III star, while lighter species like carbon, nitrogen, and oxygen were ejected.

Abel says a 25-solar-mass object is close enough to his original estimate of a Population III star's mass (30 to 300 suns) but cautions that predicting the exact mix of elements blown out in a supernova is dicey. "Just because a model gives you the right answer in one case doesn't mean it's right." Looking on the bright side, Abel adds, "It's intriguing that you might be able to make a star like HE 0107–5240 with just one supernova, which means we might be seeing a true second-generation star."

Searching for Population II

To test the Umeda-Nomoto model and settle the matter conclusively, astronomers now seek a bigger sample of extremely metal-poor stars. "If we had more stars like HE 0107–5240, we could compute the mass distribution of the first generation of stars," notes Christlieb. The hope is to use observations of second-generation stars to deduce the mass range of the original stars and the amount of metals they produced. Fortunately, Christlieb says, a few more good candidates are likely to emerge from the Hamburg/ESO Survey that discovered HE 0107–5240.

And that's just the tip of the iceberg, claims Beers. By the time the Sloan Digital Sky Survey wraps up in 2005, spectral measurements should be available for 100,000 stars. Of those, Beers expects to find 5,000 low-metal stars, some of which could be bona fide second-generation candidates. Meanwhile, the Radial Velocity Experiment (RAVE), which began on a limited basis in 2003 with a 1.2-meter telescope in eastern Australia, should be fully underway in 2006. RAVE's goals are undeniably ambitious: to measure the radial velocity, metallicity, and element-abundance ratios of the 50 million brightest stars in our galaxy.

There's even more in the pipeline: The Swift observatory, scheduled for launch in November 2004, should be able to spot gamma-ray bursts produced by the earliest stars — albeit at the exact moment of their deaths. In 2011, the James Webb Space Telescope should see the very first supernovae, revealing untold details about a star's contents before its final blast.

Pooling all that information will help clarify our presently murky views of the early universe. Although Tom Abel's depictions of the first stars represent "the current state of the art," according to Princeton University's David Spergel, they are subject to inherent uncertainties — a caveat that also applies to the models of Bromm, Hernquist, and other leading players in the simulation game. Our grasp of star formation and supernovae is still too spotty for astronomers to represent such phenomena confidently on a computer.

As new data stream in from various fronts, stellar astronomers certainly will take notice, but so will cosmologists. A big part of cosmology, explains Spergel, is trying to reconstruct the history of the universe, "learning about the first objects that formed, how they changed things, and what came next."

Searching for second-generation stars — which are, in all likelihood, the earliest stars we could ever hope to see — is a way of doing cosmology in our own neighborhood, says Bromm. The traditional way of surveying the distant past is to look far into space, pushing to as high a redshift as possible. Another strategy is to study ancient stellar fossils at low redshift, right here in the Milky Way Galaxy. "These are complementary ways of probing the early universe, and we need them all," he says. "It's important to have multiple approaches, because nature is shadowy — it doesn't give up its secrets easily." A

To see a simulation showing the formation of the first stars, visit www.astronomy.com/toc

NASA's visionary

WIth cutting-edge space missions in her purview, astrophysicist Anne Kinney is poised to push NASA into new worlds of discovery. /// BY WILLIAM SCHOMAKER

As director of NASA's Astronomy and Physics division, Anne Kinney has first dibs and last call on issues for three dozen of the most innovative, envelope-pushing missions in the universe. Such projects include veteran space missions like the Hubble Space Telescope and Chandra X-ray Observatory; "new kids on the block" with names like the Spitzer Space Telescope and Wilkinson Microwave Anisotropy Probe; and those "glimmers in the eyes of astronomers" like the highly anticipated Terrestrial Planet Finder, which promises to find earthlike oases in the abyss of outer space within the next decade.

Kinney, who grew up in Lancaster, Wisconsin, credits her father for her pursuit of a science career. As a Navy minesweeper and communications officer during World War II, "dad spent a lot of time in the middle of the Pacific in the dark, and so he taught himself celestial navigation," she says. "And he was really good at identifying stars. Even if the sky was cloudy, he was always pointing them out to me. If you're looking up every time you walk outside, it simply lodges the sky in your mind. For so long, he was the one looking up and pointing, and after a while, I was the one looking up." Patrick Kinney died February 24, 2004, just a few weeks after I met Anne Kinney at the American Astronomical Society (AAS) meeting in Atlanta. He was 86 years old.

ANNE KINNEY is optimistic about where science and space exploration are headed. "Every day is progress," she says. As the director of the Astronomy and Physics division at NASA, she would know: She oversees three-dozen missions that explore beyond our solar system, including those in search of exoplanets. ALL PHOTOS: GREGORY MILLER

WILLIAM SCHOMAKER: I understand that taking extended trips between schooling was important in your family. Where did that come from?

ANNE KINNEY: It was a tradition in my family, which again my father had started. He made the big mistake of telling us stories about this trip he had taken as a kid, [hopping] trains out West. And so we grew up with this kind of myth of the "great journey."

WS: Where did you go?

AK: I started out in Europe, spent some time in Crete, spent some time in Prague, went to Israel and worked on a kibbutz for a couple of months and then went East from there, through Iran and Afghanistan and India.

That trip [after freshman year of college] helped me to grow up. It gave me an extra 2 years. You know it's so hard to go from high school into college, which is so theoretical in some sense, and have the determination to do something difficult.

The time off, the reading I did, and thinking about science really focused my attention on what I wanted to do. And when I returned to attend the University of Wisconsin in Madison, I never took anything but math, physics, and astronomy.

WS: I understand Lincoln Barnett's book *The Universe and Dr. Einstein* had a strong influence on you.

AK: A girlfriend was reading it on the trip and I borrowed it. Barnett took a subject that was rather opaque to the general public and worked so hard to make it accessible. To take on a difficult topic and feel like I could understand it was intriguing and seductive and helped me realize that I could be an astronomer.

I came from a high school that didn't offer a lot of math and physics. And though I took every class available to me, I went into college without a great background, relative to kids who grew up in the big cities. I mean, I hadn't even had trigonometry. I was coming from behind, and I think it helped me to work my way through a book that was, granted, not at a professional level, but a serious book nonetheless.

Kinney tells a story about her first annual review as a tenure-track employee with the director of the Space Telescope Science Institute in Baltimore (STScI), then Riccardo Giacconi. Her colleagues had warned her she should be prepared to discuss her long-term goals. Kinney realized, then, she hadn't thought about long-term goals because there weren't many examples of senior women in the field.

William Schomaker *is a contributing editor of* Astronomy. *He writes* Interview *each month.*

During the early years of Kinney's professional education and career, gender issues kept poking to the forefront. She recalls wearing a skirt and blouse to her undergraduate optics class one day and the 40 pairs of eyes that escorted her across the room to her seat. That skirt didn't come out of her closet again for 5 years. Then there were the disappointing interactions with male colleagues who seemed always to focus on what Kinney calls "a woman's second set of eyes."

Kinney made it clear the first time I spoke with her, on the phone a few weeks before we met, that she's grown somewhat weary of the discussion about women and equality within the ranks of astronomy. She's tired of the same old rhetoric. The issue needs less discussion and more action to achieve any form of resolution. Despite the warnings, I pursue the line of questioning with the hope that her comments will make a difference.

WS: Tell me about some of your early inspirations in the field that got you through the rough times.

AK: I think one bright little beacon in those early days as an undergraduate, when there were just no women at all, was reading an American Astronomical Society newsletter and seeing the name of the president, who was Margaret Burbidge. Even though I didn't know any women in astronomy, and there weren't any in the department at the University of Wisconsin at that time, it was clear that women could be prominent in the field. So I think that was also a little glimmer of hope in terms of actually having some kind of future.

"We don't want a situation where no gifted woman is going to go into [astronomy] because she looks and she sees only men at the top of the field. That's an unforgivable situation, I think." – ANNE KINNEY

WS: A recent study by the United States Bureau of Labor Statistics shows women hold 51 percent of all white-collar management jobs in America. Meanwhile, women occupy only 6 percent of the top jobs in astronomy. What is the astronomy community missing by having so few women in the top ranks?

AK: You always want access to all of the available brainpower. Remember, that 6-percent figure can be a little misleading. If you look at the number of people graduating with astronomy Ph.D.s, it's much more even between men and women now. It's those steps after graduating that make the difference. Getting a post-doc isn't that hard. Going from post-doc to a tenure-track position is harder. And moving to a tenured position is really hard. Getting on the tenure track involves really long work hours, which isn't always [conducive to] raising a family.

Granted, there are lots of different ways we could solve this problem, such as increased flexibility in the workplace and that sort of thing. The way we don't want to solve it is to ever compromise the quality of the field. Science is hard. You don't want to force a solution that ends up with any lesser quality. That probably comes off sounding a lot like an apologist. I don't mean to sound

Exosolar planet finding is a key part of the science we are doing in the Universe Division.

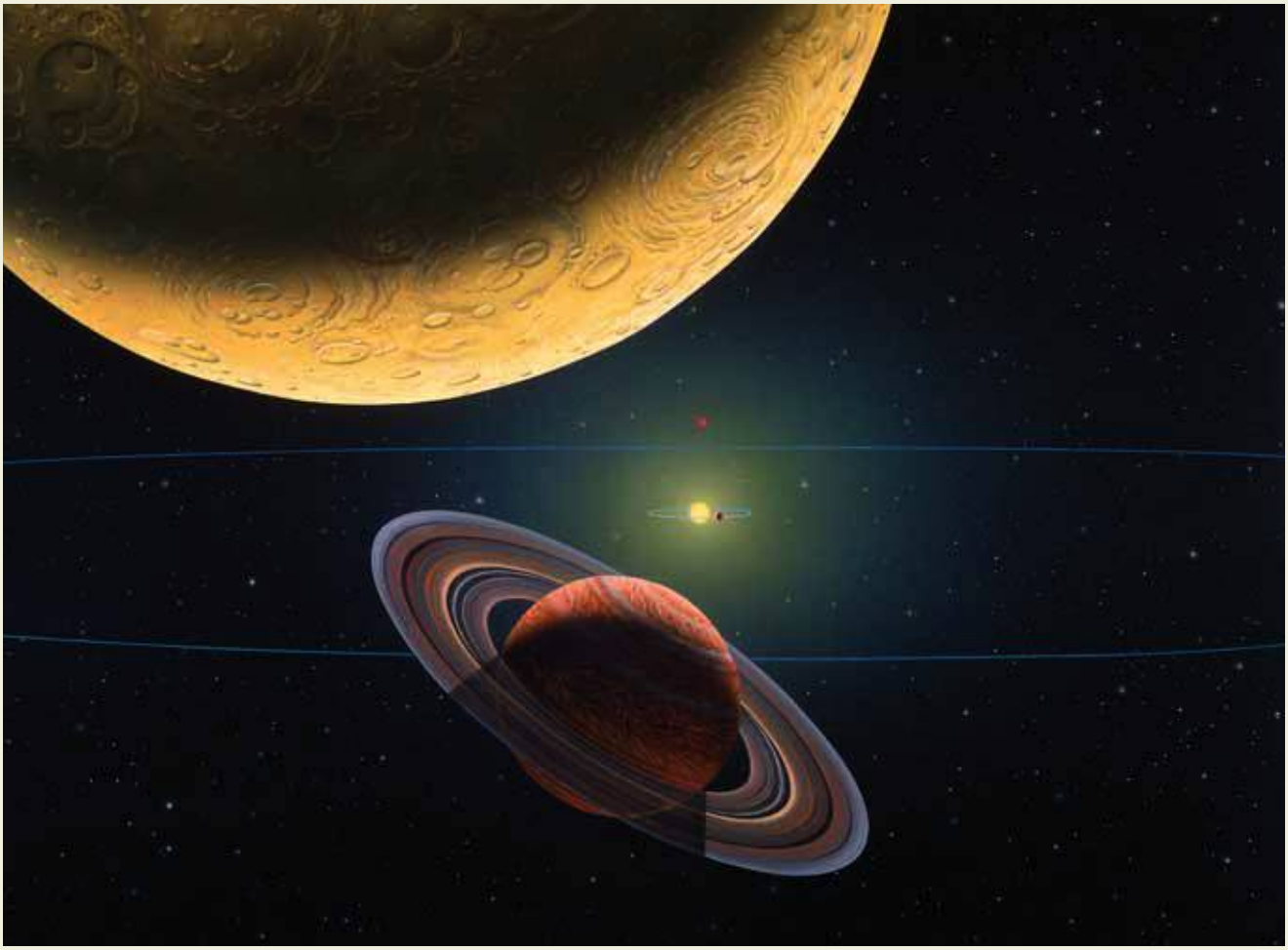
One way to look at it is this: In the last century, great astronomy was performed on telescopes built to solve cosmology — in this century, great astronomy will be performed on telescopes designed and built to find earthlike planets.

It is one of the biggest questions we face: Are there other planets out there like our own — and do they host life? The current result is important because all the early planet discoveries were of massive planets — Jupiter mass, very close in — so not earthlike and also not solar-system like.

Once you have 100 discoveries and they are all massive, you tend to think that is all that is out there — so getting proof that there really are Neptune-mass planets is a big step.

Our goal is to build a terrestrial-planet finding telescope by 2014 — to detect earthlike planets and to look for signatures of life. This is at the edge of our capability, but I believe [it is] doable.

Can you imagine being the generation that discovers life outside our solar system? That is a discovery that would rank as the most important ever made. — *Anne Kinney*



THE CONTINUING SEARCH FOR EXOPLANETS may yield even greater returns — earthlike planets around Sun-like stars, and possibly life. LYNETTE COOK

that way. I mean, look at the alternative: We don't want a situation where no gifted woman is going to go into the field because she looks and she sees only men at the top of the field. That's an unforgivable situation, I think.

Kinney finished her studies at the Niels Bohr Institute and the Copenhagen Observatory in Copenhagen, Denmark, and New York University (NYU) back in the United States. Her Ph.D. thesis, featuring quasar observations with the International Ultraviolet Explorer (IUE) satellite, was the first extragalactic astronomy thesis at NYU.

She spent the next 14 years working on Hubble at the STScI. For most of that time, Kinney worked as an instrument scientist on the telescope's Faint Object Spectrograph (FOS). She worked tirelessly to debug the spectrograph's target acquisition algorithms, "It's hard work, and it's not always so exciting," says Kinney. "But that's what you need to do when you're making a telescope like Hubble work. The whole idea is to push the envelope, with every part of the telescope — the detectors, the cooling mechanisms, the mirrors — with absolutely everything, because that's the only way to make scientific advances."

The work would pay huge dividends later, with the groundbreaking capture of a spectral velocity signature from a supermassive black hole in M87. "To detect the huge change in velocity due to matter orbiting very quickly around the black hole, we had to be able to do perfect target acquisition or [the FOS] was useless."

At STScI, Kinney also worked on observations of accretion disks in active galaxies using radio jets as tracers of disk position and

alignment, as well as compiling data for her galaxy atlases. Fellow astronomers come up to her at meetings, as they did at the 2004 AAS meeting in Atlanta, to inquire about her extragalactic atlases.

In her current role with NASA, Kinney spends most of her time managing present and future missions. "Finding and fixing things going wrong, taking advantage of things going right, and staying on budget and doing it all with lots of collaboration with the astronomy community involves about a dozen skills you never learned in school," says Kinney. "Most important is having the ability to keep the big picture and to have the wisdom to evaluate what's important and urgent and to do what's important."

What's more, the Office of Space Science reinvents itself every 3 years to ensure fresh ideas are always flowing in. As Kinney explains, the 3-year cycle results from the "natural ebb and flow of creativity."

"The expression is that 'planning is everything and that plans are nothing.' It's like painting the Golden Gate Bridge. It takes 3 years to paint the Golden Gate, and when you're done, you start over and paint it again."

As we press on, I'm comforted by Kinney's levelheaded approach to NASA's outreach duties. She headed the education department of NASA's Office of Public Outreach from 1996 to 1999. Like her current boss, Ed Weiler, associate administrator of space science enterprise at NASA, says, "outreach is core to Kinney's personality."

"You can read the values of our culture in the front page of the newspaper and the headlines of the evening news," says Kinney. "Why should we want every single headline to be a fire and a murder and a drug deal and a war? I think you do a real service to science educators when you get astronomy stories out. It's like a statement from society that says 'we value what you teach and we're going to help you do it.'" To Kinney, outreach isn't about producing more astronomers as much as it's about inspiring kids to get technical backgrounds so they'll have a wide set of skills and choices related to technology and progress.

WS: How do you feel about the decision to cancel future servicing missions to Hubble?

AK: It was a really difficult decision for the agency and a loss for me personally, but I think it was the right decision because it was based on safety, and you can't compromise safety.

Hubble is up and operating right now and we've got a bunch of ingenious people working on it, and I suspect that they'll have a new motivation to operate it in a way that pays a lot of attention to extending its lifetime. I'm very optimistic about how long we'll keep Hubble going.

WS: Were you surprised by the outcry from the public and the astronomy community?

AK: Four days before the agency announced its decision, our Hubble program manager came to me and said, 'One of my biggest concerns is that I don't see how we're going to do return-to-flight for Hubble.' People here were very concerned about it, people who were a little closer to the return-to-flight issues surrounding Columbia. But no, I'm not surprised that there was an outcry, because [the servicing missions] were cancelled for a set of reasons that the astronomy community does not have any expertise with.

WS: Has Hubble lived up to its original promise?

AK: Absolutely!

WS: Why not be content with 14 years of service and let Hubble retire its place in history?

> "The whole idea is to push the envelope, with every part of the telescope – the detectors, the cooling mechanisms, the mirrors – with absolutely everything, because that's the only way to make scientific advances." – ANNE KINNEY

AK: You'd be preaching to the converted if you said that to me. I recently dug up the original science goals of Hubble. To date, it has met or exceeded every single science goal, and in some cases, of course, it has wildly exceeded those goals.

WS: Such as?

AK: I think the best example is always the Hubble Deep Field and the continuing deep fields that have come out of it. People had no idea what a breakthrough it would be, that Hubble was going to crack open the deep sky like that.

At the end of the interview, we drift into conversation about hopes for the future and inspiration. Kinney admits she is most inspired by the Terrestrial Planet Finder mission. "Every time you go to a planet-finding meeting, the community has almost doubled in size," she says. "So it's a field that's about to enter its Golden Age. It's sort of like you've turned around and find that the room is suddenly full of people. And that's exciting to be involved with a brand-new field of science that hasn't existed before."

We say our goodbyes and go our separate ways. I'm alone with a flood of thoughts converging on a central theme — any one of my tax dollars that winds up under Kinney's budget is one I know is in good hands, one I'm proud to spend. Kinney communicates her understanding of science's role in society better than anyone I've ever met. Her parting comments still haunt me for their sublime clarity: "Remember that scientific questions are questions that we approach. We will hack away at these questions now, and it may not be entirely clear to us when we've arrived at the answer, but eventually, we will arrive. And that's all that matters. Every day is progress." A

Watch a press conference chaired by Anne Kinney on the discovery of three exoplanets at www.astronomy.com/toc

OUTREACH IS IMPORTANT TO KINNEY, who believes math and science education provides children with special skills. In 2004, she was the national spokesperson for Space Day, an educational initiative designed to inspire and prepare kids for careers in science and engineering.

BY MARTIN RATCLIFFE AND ALISTER LING

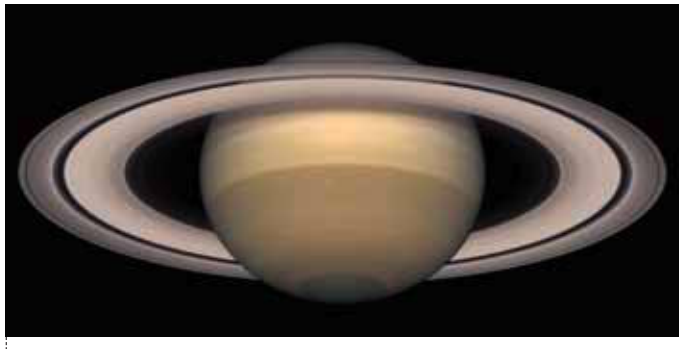
JANUARY 05

The view of Saturn through a telescope draws gasps from newcomers, but a gorgeous new comet might leave you speechless as it passes the Pleiades star cluster.

Saturn reigns supreme

Picture-perfect Saturn and its glorious ring system hit their peak in January. On the 13th, the planet reaches opposition, when it lines up with the Sun and Earth. Saturn then appears biggest and brightest and remains visible the whole night.

Unfortunately, opposition also marks a time when shadows disappear — and shadows help give Saturn a 3-D appearance. In early January, look closely where the edge of Saturn's globe covers the rings, and you will see a dark line. A couple of days before opposition, that line becomes invisible. But as the nights roll by after opposition, the shadow reappears on the opposite side and slowly thickens into an obvious strip.



SATURN GLEAMS BRIGHTLY and looms large this month as it reaches the peak of its current apparition. NASA AND THE HUBBLE HERITAGE TEAM (STScI/AURA)

Your best view of Saturn, or any object for that matter, comes when it stands highest in the sky. That position minimizes the turbulence caused by Earth's atmosphere and any local heat sources.

In centuries past, planets were recognized as special because, unlike other bright points of light in the sky, they wandered. Every week, compare Saturn's position with the bright stars Pollux and Castor. The planet's path is a combination of its own movement and Earth's faster pace.

Faster yet are the inner planets Mercury and Venus. In the 4 weeks beginning December 20, Mercury rises above Venus in the morning sky, executes a hairpin turn (from our perspective), and then drops back beneath the blazing beacon. It would be cool to make a time-lapse movie of this event, something within easy reach using a digital camera and software.

Mars continues to speed eastward against the rising stars at dawn. It is the modest, rusty-orange "star" to the upper right of Venus. The second orange object in the area is the red supergiant Antares, whose name means "rival of Mars." Antares lies lower than Mars during the first 10 days of January then pulls away to the planet's right as seen from the Northern Hemisphere. You can tell the two apart because Antares shines brighter than Mars all month. A lovely waning crescent Moon joins the pair the morning of the 7th.

Jupiter rises around midnight in the company of Virgo the Maiden and that constellation's brightest star, blue-white Spica. The giant planet easily dominates the southern sky as dawn approaches. For lucky observers in southern Australia, from Perth to Adelaide, the Moon covers Jupiter during daylight January 4.

Veteran comet-hunter Don Machholz discovered his 10th comet in late August, scooping the search programs that use robotic telescopes. Comet C/2004 Q2 (Machholz) should peak this month at around 4th magnitude, so you'll be able to see it with the naked eye from a dark location. With the Moon out of the way and January 7 being a Friday night, head to the country with your binoculars and a telescope. You won't want to miss the comet's thin blue ion tail streaking just above the Pleiades while its yellow-white dust tail curves through the rich star group. If you stay in the city, you'll risk having skyglow eat it all up except for the condensation around the comet's core.

Probably the third favorite meteor shower of the year, after the Perseids and the Geminids, peaks the morning of January 3. The Quadrantids can reach a rate of 120 meteors per hour — higher than its more famous cousins — but January weather and a brief peak that severely limits the number visible on any other night conspire against the shower. This year, light from the Last Quarter Moon will take another notch out of the Quadrantids. What appear to be "shooting stars" are, in reality, grains of dust burning up as they slam into Earth's upper atmosphere at 92,000 mph (148,000 km/hour).

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AutoStar® – LNT™ – SmartFinder™

When you ask owners what they like most about their Meade LX90 telescope they will invariably reply, "excellent optics, incredible pointing and tracking accuracy, portability and of course – AutoStar." The LX90 was also rigorously tested and reviewed by Sky & Telescope and Astronomy Magazine. Here is what they wrote regarding their test results:

DIFFRACTION-LIMITED OPTICS

"The LX90 performed beautifully on splitting colorful and close double stars.... Antares is easy to split in an 8-inch. What makes it difficult to resolve sometimes is not the separation (3"), but the difference in brightness between the 1st-magnitude primary and its 7th magnitude companion. The LX90 split it with ease and revealed the duo's nice orange-blue color contrast as well.... The optics in the LX90 were defect-free." ***– Astronomy Magazine***

POINTING & TRACKING ACCURACY

"The altazimuth tracking was excellent. One evening I centered the Whirlpool Galaxy, M51, in the eyepiece and let the scope track unattended as the galaxy rose in the northeast and passed near the zenith. After more than four hours it was still dead-center in the field.... The computer pointing is also remarkably accurate." ***– Sky & Telescope Magazine***

AUTOSTAR

"They make it easy for beginners to explore the sky and grant experienced observers more time looking at objects than hunting them.... Having AutoStar at my fingertips easily tripled the number of targets I viewed in the space of a few hours. A key feature for experienced observers, you can observe more targets in a given time." ***– Astronomy Magazine***

ASTROPHOTOGRAPHY

"With a strong background in astrophotography, I was particularly interested to see if the LX90 would live up to its claims. The short answer? It certainly does, and then some." ***– Sky & Telescope Magazine***

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Viewfinder	8x50 Optical & LNT Red Dot
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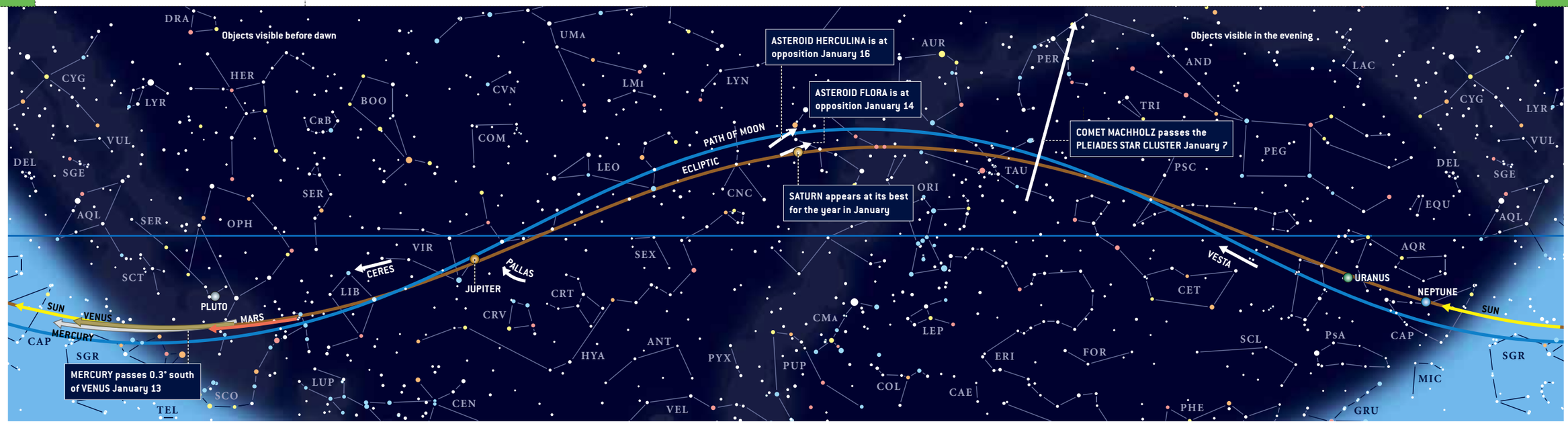
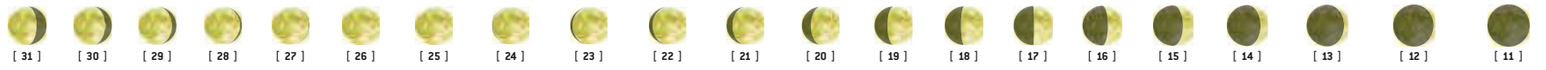
Planets this month

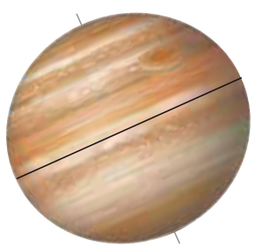
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

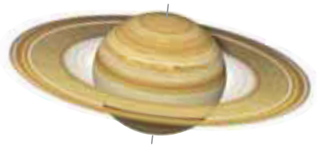


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.



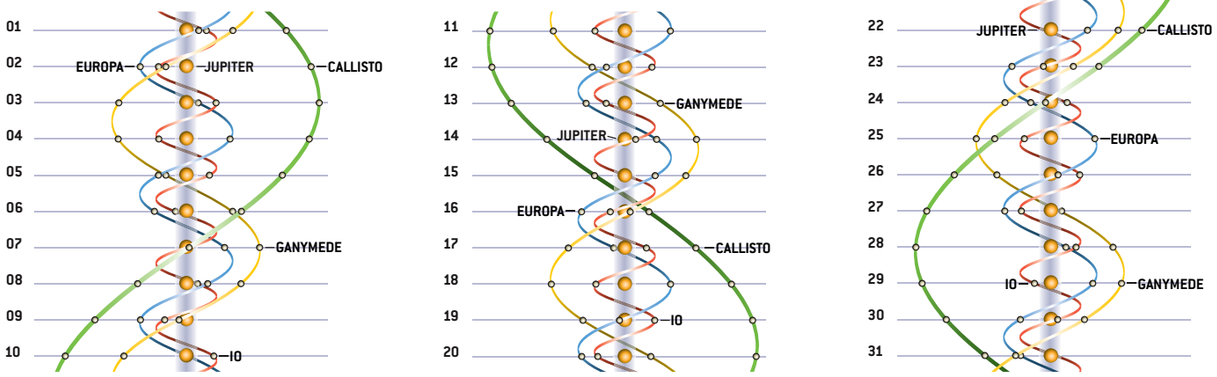
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	January 1	January 15	January 15	January 15	January 15	January 15	January 15	January 15	January 15
Magnitude	−0.4	−0.5	−3.7	1.5	−2.1	−0.4	5.9	8.0	14.0
Angular Size	6.4"	5.3"	10.5"	4.3"	37.5"	20.6"	3.4"	2.2"	0.1"
Illumination	69%	87%	95%	95%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.059	1.275	1.591	2.156	5.253	8.076	20.807	30.992	31.722
Distance (AU) from Sun	0.402	0.458	0.726	1.552	5.455	9.059	20.059	30.066	30.898
Right Ascension (2000.0)	17h09.9m	18h29.4m	18h28.6m	16h50.5m	13h09.5m	7h42.4m	22h26.4m	21h07.1m	17h31.9m
Declination (2000.0)	−21°12'	−23°33'	−23°08'	−22°29'	−5°55'	21°22'	−10°34'	−16°38'	−15°13'

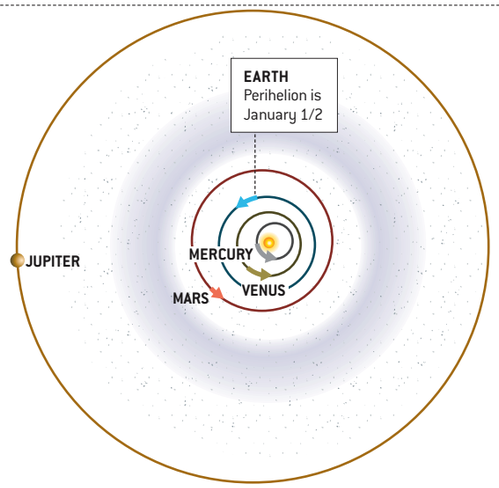




Jupiter's moons

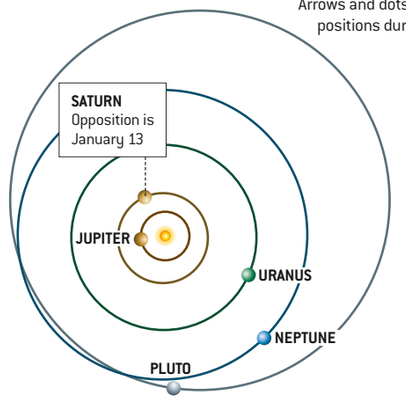
Dots display positions of Galilean satellites at 4 A.M. EST on date shown. South is at top to match the view in a telescope.





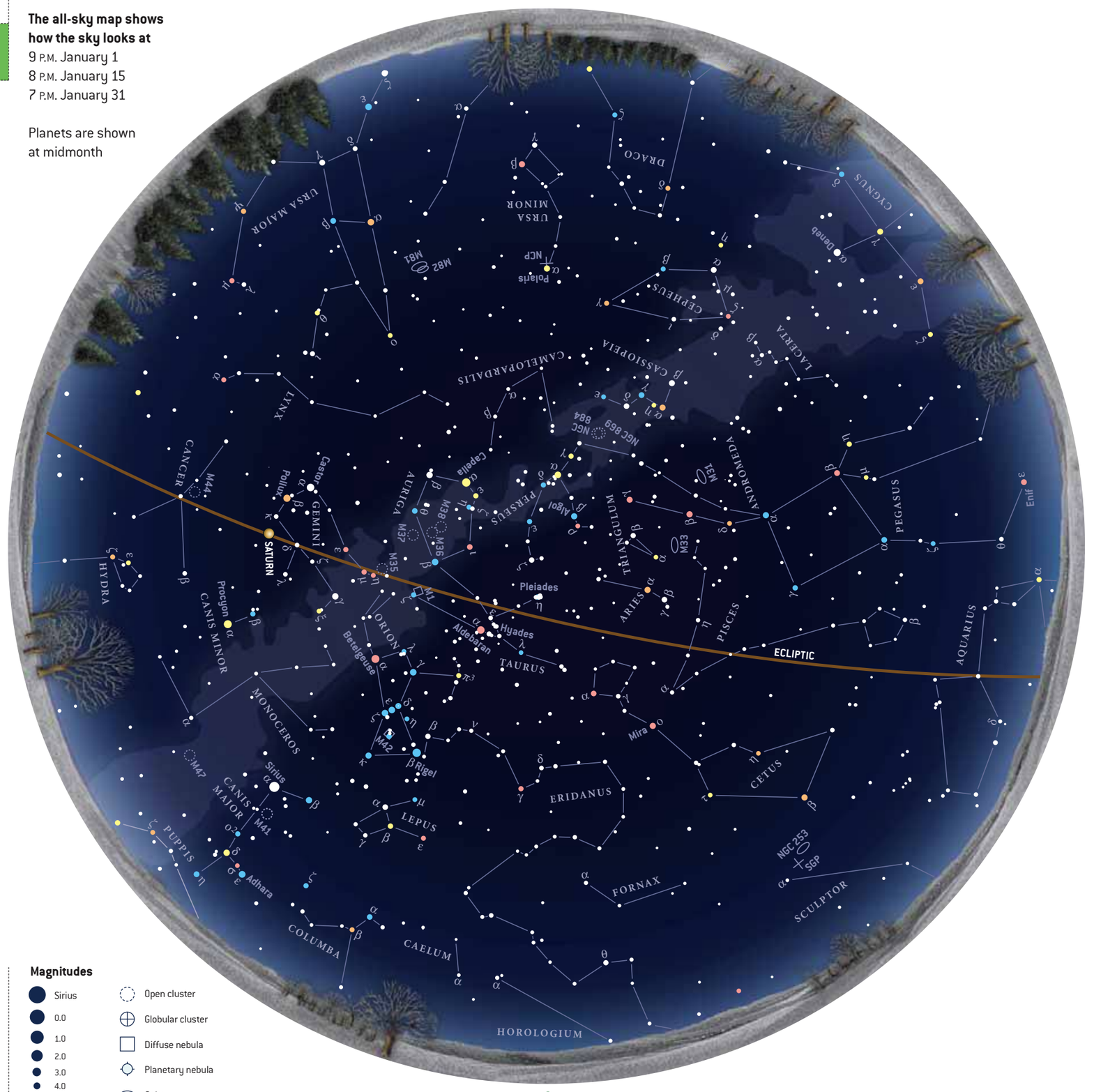
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

january 05

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						[01]
[02]	[03]	[04]	[05]	[06]	[07]	[08]
[09]	[10]	[11]	[12]	[13]	[14]	[15]
[16]	[17]	[18]	[19]	[20]	[21]	[22]
[23]	[24]	[25]	[26]	[27]	[28]	[29]
[30]	[31]					

01 Earth is at perihelion (91.4 million miles from Earth), 8 P.M. EST

03 Quadrantid meteor shower peaks

Last Quarter Moon is at 12:46 P.M. EST

The Moon passes 0.4° south of Jupiter, 9 P.M. EST

06 Saturn passes 7° south of Pollux, 5 A.M. EST

07 The Moon passes 3° south of Mars, 2 P.M. EST

The Moon passes 1.3° north of Antares, 3 P.M. EST

Mars passes 5° north of Antares, 4 P.M. EST

08 The Moon passes 5° south of Mercury, 9 P.M. EST

The Moon passes 5° south of Venus, 10 P.M. EST

10 The Moon is at perigee (221,562 miles from Earth), 5:07 A.M. EST

New Moon is at 7:03 A.M. EST

13 The Moon passes 4° south of Uranus, 3 A.M. EST

Saturn is at opposition, 6 P.M. EST

Mercury passes 0.3° south of Venus, 8 P.M. EST

17 First Quarter Moon is at 1:57 A.M. EST

23 The Moon is at apogee (252,553 miles from Earth), 1:53 P.M. EST

24 The Moon passes 5° north of Saturn, 3 A.M. EST

25 Full Moon is at 5:32 A.M. EST

31 The Moon passes 0.9° south of Jupiter, 6 A.M. EST

For definitions of terms, visit www.astronomy.com/glossary

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Focal Ratio	f/10	f/10	f/10	f/10	f/10	f/15
Focal Length	2000mm	2500mm	3048mm	3556mm	4064mm	2670mm
Corrector Lens	water white	water white	water white	water white	BK7	BK7
Primary Mirror	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®	Pyrex®
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LPI/Autostar Suite ($149 value)	FREE	FREE	FREE	FREE	FREE	FREE

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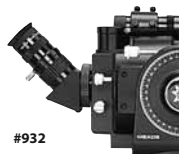

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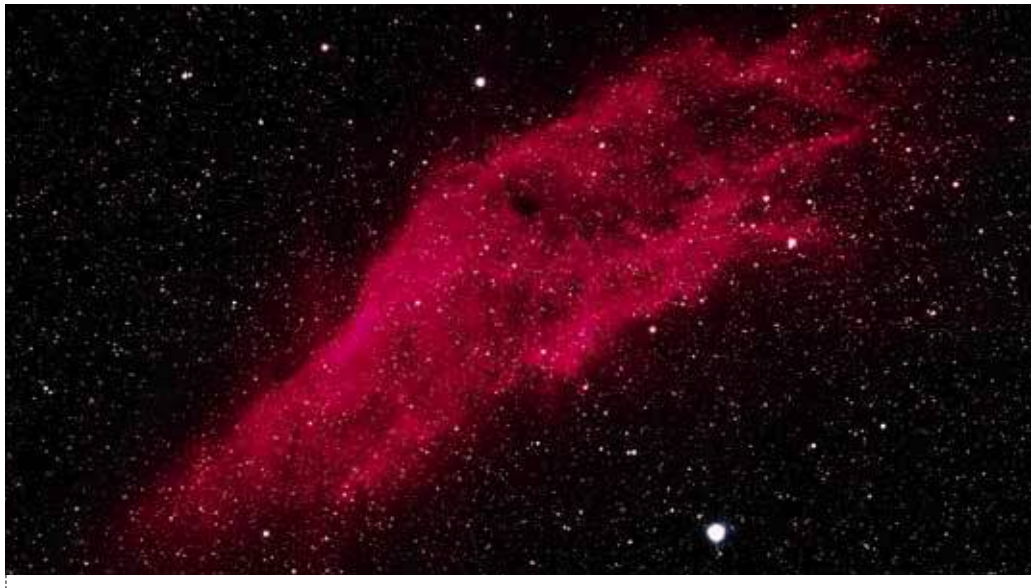
THE DEEP SKY

Stars may be the most visible form of the hydrogen that permeates the universe, but the most intriguing and beautiful shapes belong to glowing emission nebulae.

Distant shores

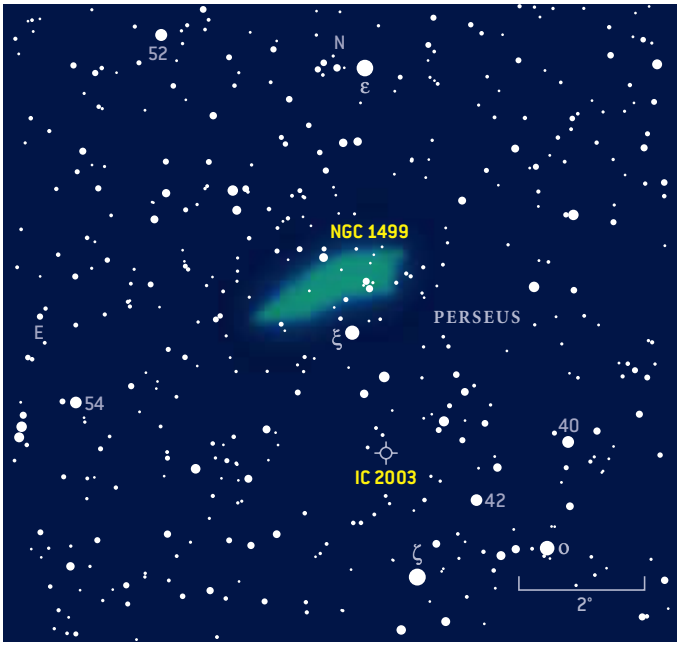
The California Nebula (NGC 1499) in Perseus has to rank among the most widely recognized and photographed clouds of hydrogen in the sky. Although possible to capture in a 30-second exposure on ISO 400 film, the California remains difficult to detect visually. It eluded such great observers as William and John Herschel and Lord Rosse. It had to await the eagle eyes of E. E. Barnard, who discovered several large objects by sweeping the sky with a 6-inch refractor at low power.

More than any instrument, you will need a sky as black as possible to spy it. The California has such low contrast that even a little bit of skyglow from cities, the Moon, or snow cover will hide it.



THE CALIFORNIA NEBULA (NGC 1499) in Perseus shows lots of detail when viewed through a nebula filter. GEORGE GREANEY

Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*



Next, you have to be truly dark adapted. Allow at least 30 minutes for your pupils to dilate. As much as possible, avoid looking at even a red flashlight; cover your observing eye while reading star charts.

Begin your search with binoculars, sweeping slowly back and forth across the area. In most cases, you won't so much see a nebula as detect a rise and fall in the background brightness. The northeastern edge of the California has the most contrast. Sweeping uses the eye/brain combination's built-in survival skill to detect moving objects in low light conditions. Large telescopes won't help because their narrow fields of view will peer right through the ghostly sheet.

Several observers have seen the California using only a paper tube and a nebula filter. Such a high-tech filter is an invaluable accessory for even the casual deep-sky observer. Manufacturers design nebula filters to block out light except at the specific wavelengths emitted by ionized gas, thereby cranking up the contrast.

Standing out

Starkly opposite the California Nebula in every way is the diminutive planetary nebula IC 2003. Although it glows faintly at magnitude 11.5, its tiny, 7"-diameter disk gives it a lot of contrast. In many ways, IC 2003 resembles a fainter echo of the planet Uranus. Try passing a nebula filter back and forth between your eye and the eyepiece. This so-called blinking technique makes small planetaries pop out of the field because the filter suppresses surrounding stars.

THE PLANETS

Saturn reaches the peak of its current apparition in January, dominating the long winter nights until four other planets rise during the morning hours.

As darkness falls on January evenings, **Saturn** can be seen rising in the east. The ringed planet reaches opposition January 13, when it lies opposite the Sun in our sky. That means it rises at sunset, appears highest in the south around midnight, and sets at dawn. Opposition also marks the time when the planet lies closest to Earth, so it shines brighter and appears larger through a telescope. But the view changes slowly, and Saturn appears magnificent throughout January.

Don't confuse Saturn with either of the bright stars above it: Castor and Pollux in Gemini. Both stars rise before Saturn, and the planet, which shines at magnitude –0.4, appears noticeably brighter. At opposition, Saturn lies 7° south of Pollux. Between January 25 and 27, the ringed planet slides in front of the open star cluster NGC 2420. This 8th-magnitude cluster creates a pretty backdrop, but will make identifying the planet's moons much harder.

Saturn's disk measures 20.6" across at opposition and its spectacular rings span 46.7" at their widest. Saturn lies about 750 million miles from Earth — a fair distance, but close enough that even the smallest scope will show the rings easily. You should have no problem spying the Cassini Division, which separates the outer A ring from the brighter B ring. With a large scope, you also should be able to spot the innermost C ring.

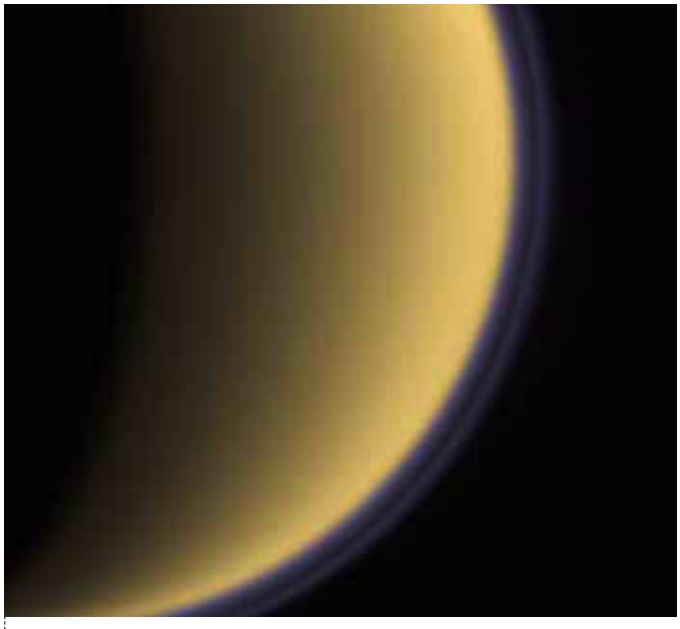
As Saturn nears opposition and the Sun's light comes from almost directly behind Earth, the shadow that the planet casts on the rings appears to shrink. It actually disappears from view the week of opposition. Earthly atmospheric conditions and the size of your telescope affect the shadow's visibility, with large scopes better able to follow the declining shadow. How long can you keep track of the planet's shadow on the rings?

The day after opposition, January 14, should mark the climax of the 7-year voyage of the Huygens spacecraft. This instrument-packed probe, a vital part of the Cassini spacecraft, will descend through the atmosphere of Saturn's largest moon, Titan. It may reach the moon's surface — to crash or to splash, no one knows. The probe could land on solid ground or in a sea of liquid methane.

There's something exhilarating about viewing a celestial object when a space probe performs some spectacular feat. On January 13/14, you can find Titan northeast of Saturn; the following night, the moon sits due north of the planet. Check the Cassini/Huygens web site (*saturn.jpl.nasa.gov/home/index.cfm*) for up-to-date times of Huygens's descent into Titan's atmosphere.

Almost any telescope reveals Titan, which glows at magnitude 8.3. On January 6/7, Titan lies south of Saturn, and the moon returns to that position again one orbit later, on January 22/23. Don't confuse Titan with the 8th-magnitude star that lies north of Saturn January 17/18. Titan lies west of Saturn that night.

It's also worth checking out Saturn's other moons, even if they don't receive any spacecraft visits this month. A 6-inch scope easily shows



SATURN'S MOON TITAN greets the Huygens probe January 14, when we should see the haze-covered world's surface in unequaled detail. NASA/JPL/SSI

three 10th-magnitude moons: Tethys, Dione, and Rhea, in order of increasing distance from Saturn. You'll probably need a larger aperture to find 12th-magnitude Enceladus and 13th-magnitude Mimas, which orbit close to Saturn and can be hard to see in the planet's glare.

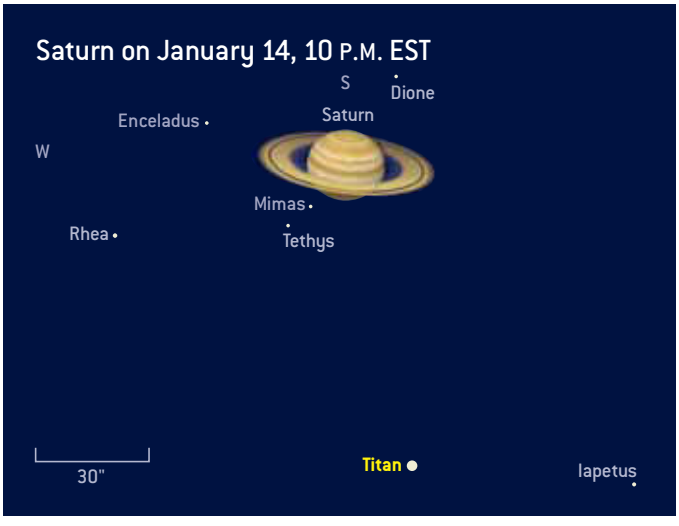
Two-faced Iapetus glows at 12th magnitude in early January but brightens by a factor of five by the end of the month, when we see more of its brighter hemisphere. During January, Iapetus moves from east of Saturn to the western side, passing due north on the 16th.

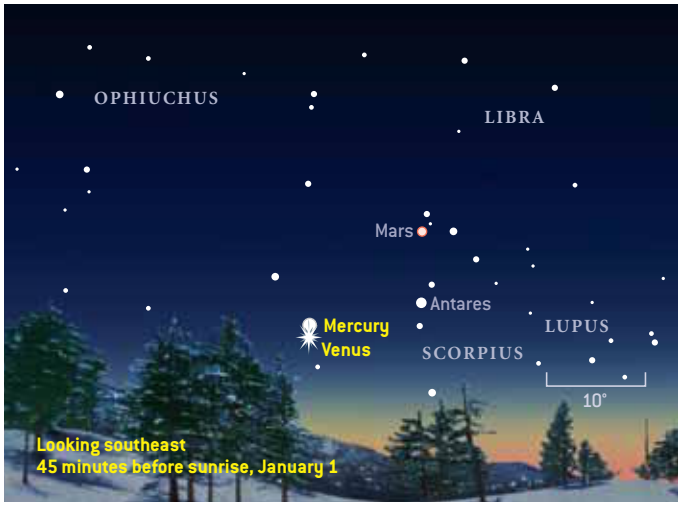
By the time the night is half over, you can start looking for **Jupiter**. The giant planet rises around 1 A.M. on New Year's Day but breaks the eastern horizon by 11 P.M. on the 31st. Jupiter spends the month 6° northwest of Virgo's brightest star, Spica. You'll also find the planet 5° above a fat crescent Moon on the 4th and 1° north of a gibbous Moon on the 31st.

Backyard telescopes give wonderful views of Jupiter because the planet has a relatively large disk. This month, it averages 38" across, making details easy to see. The two dark equatorial belts are the most obvious sights at any magnification. It takes a few minutes of patient observing to accustom your eyes to seeing smaller and finer features — so don't rush. Moments of steady atmospheric seeing will reward you with great detail.

Avoid the temptation to observe a planet as soon as it rises, especially in winter. The combined effects of atmospheric turbulence, particularly when viewing through thick layers of air near the horizon, and local turbulence created by residential heat during the colder months, deliver poor views. Don't blame your scope immediately if an image lacks clarity — allow it to cool to the outside temperature and let the planet rise at least 10° to 15° above the horizon before expecting a good image.

After Jupiter appears, there's another long wait before the next planet rises. **Mars** clears the horizon by 5 A.M. local time throughout January. On the 1st, it stands 7° above the 1.0-magnitude star Antares, the famous "rival of Mars." Mars loses the rivalry this month, shining at magnitude 1.5, but the pair appears striking nonetheless. Check out the colors of both objects. Antares shines with an orange hue because of its relatively cool surface temperature, around 4,500 kelvins. Although Mars shines with a similar color, it has nothing to do with temperature. Mars appears ruddy because sunlight reflects off its rust-colored soil.





The view of Mars through a telescope proves disappointing this month because its disk spans a meager 4". But watch for the pretty crescent Moon as it passes 5° to the right of the planet January 7. Mars moves from Scorpius into Ophiuchus January 5 and remains there the rest of the month.

Mercury and **Venus** perform an elegant dance in early January, but you'll need a clear southeastern horizon to spot them. On the 1st, Mercury rises a few minutes before 6 A.M. local time and stands 1.1° northwest of Venus. Each successive morning, Mercury swings to the west of Venus. By the 8th, it stands 0.8° west of Venus and a very thin crescent Moon lies to the pair's right. Mercury lies due west of Venus the following morning, when both planets can be seen in a low-power field of view.

Mercury and Venus appear closest to each other January 13, when only 0.3° separates them. That morning, the pair lies 6° above the southeastern horizon 30 minutes before the Sun rises. Following their close conjunction, both planets dip into brighter twilight, with Mercury sinking much faster. Although the innermost planet brightens a few tenths of a magnitude, it becomes lost in the Sun's glare by the third week of the month.

At magnitude –3.7, Venus shines far brighter than Mercury. Venus has an angular diameter of 11" and appears 93-percent lit. Mercury glows dimmer, at magnitude –0.4 in early January, and shows a 69-percent-illuminated disk measuring just 6" across.

METEORS AND MOONS

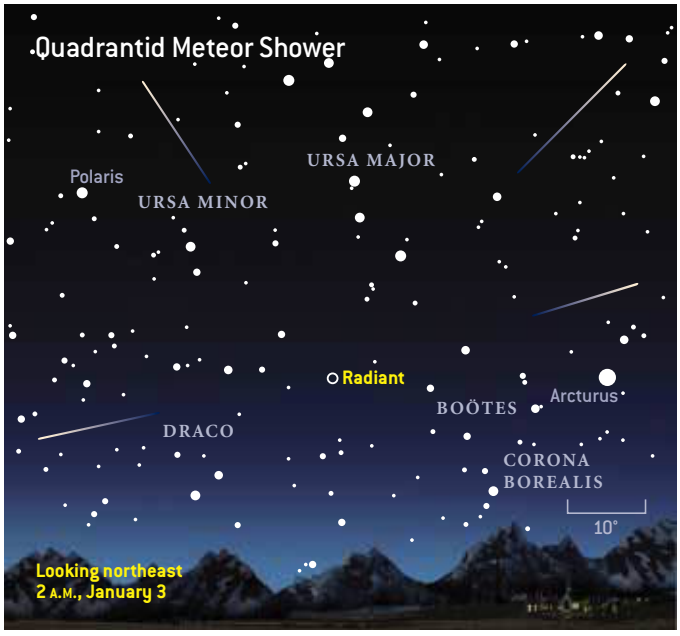
The year's first meteor shower gets 2005 off to a good start with lots of bright flashes peppering the predawn sky January 3.

Off the Wall Quadrant

The Quadrantid meteor shower peaks the morning of January 3. The year's first shower has produced high rates in recent years, up to around 120 meteors per hour. (Such great numbers appear only under a pitch-black sky with the radiant overhead, however; observed rates almost always are lower.) Unfortunately, the high rate lasts only several hours — observers rarely see many meteors even 1 day before or after the peak. Despite the large number of meteors, the short duration and often cold, cloudy weather this time of year make the Quadrantids poorly observed.

This year, astronomers expect the peak to come around 7 A.M. EST (4 A.M. PST) January 3. The Last Quarter Moon then lies high in the morning sky, however, standing just 7° from Jupiter. So while the timing of the shower favors much of the United States, the bright Moon will attenuate the number of visible meteors. Still, the potential for a good show remains. Just be sure to dress warmly, in layers, and take occasional breaks to keep from getting overly chilled.

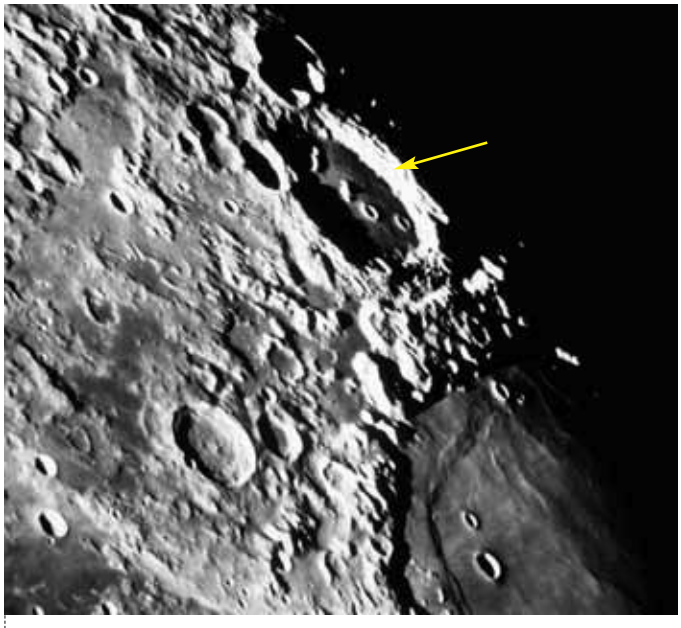
Quadrantid meteors appear to radiate from a point in the northeastern corner of Boötes the Herdsman. This region used to belong to a now-defunct constellation known as Quadrans Muralis the Wall Quadrant (or Mural Quadrant), which still lends its name to the shower.



Meteors arise when bits of cosmic debris enter Earth's atmosphere and burn up from friction with the air, producing bright streaks of light. Most meteor showers result from Earth plowing through a stream of such debris, usually left behind by a comet after innumerable trips around the Sun. Until recently, however, the Quadrantids had no identified parent comet. That changed in 2003, when Peter Jenniskens of the SETI Institute announced that near-Earth asteroid 2003 EH_1 had orbital characteristics closely matching those of the Quadrantid meteor stream. Astronomers think this object is the biggest remnant of a comet's breakup and provides the first direct link to the annual shower.

Near a lunar crisis

Just off the northwestern shore of Mare Crisium lies the fine crater Cleomedes. Because it lies near the limb of the Moon, this 78-mile-diameter (126 km) crater appears foreshortened, with its north-south extent noticeably longer than its east-west dimension. A few small craters and an elongated central mountain chain dominate the crater's floor, which otherwise appears relatively flat. The crater's walls tower 1.5 miles (2.5 km) above the floor, and a large crater called Tralles breaks the northwestern wall. When the Sun strikes Cleomedes at a low angle, you can spot a few linear rilles carving the crater floor. Look for the Sun to rise over this region when you see the new crescent in the evening sky January 13.



THE CRATER CLEOMEDES (arrow) lies northwest of Mare Crisium and comes into fine relief at low Sun angles. FROM *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

COMETS AND ASTEROIDS

Veteran comet-hunter Don Machholz once again beats the robotic telescopes to the punch. Watch this month as the tail of his new comet passes through the Pleiades.

A binocular beauty

No matter how cold it gets, bundle up, step outside, dark adapt, and have a look at a lovely comet. Passing just outside Earth's orbit, Comet C/2004 Q2 (Machholz) should be cresting around 4th magnitude as it scoots past the brilliant Pleiades star cluster January 7. The pair will be visible to the naked eye from rural areas in a celestial replay of Comet C/2001 Q4 (NEAT)'s passage by the Beehive star cluster last May.

Although no one knows for sure how long the tail will grow, we do know we'll be seeing it a bit from the side, so the tail should be streaming in the direction of the Pleiades. If we're lucky, the comet will display both a decent dust tail and a nice blue ion tail. From the city, Comet Machholz may appear as a tail-less, fuzzy ball.

The ion, or gas, tail comes from atoms and molecules energized by the Sun's ultraviolet light. They subsequently emit visible light as the electrons drop to a lower energy state, a process called fluorescence. The gas tail appears straight because the ions stream away from the Sun on the wings of the speedy solar wind.

The dust tail is just that, the dirt part of the "dirty snowball" that forms the comet's nucleus. Sunlight sublimates the snowball's ice (turning it directly from solid to gas) and releases dust particles in the process. The dust glows by reflecting sunlight. The particles get pushed away from the Sun by the gentle pressure of solar radiation, so they tend to keep orbiting with the comet. This imparts a nice curved shape to the dust tail.

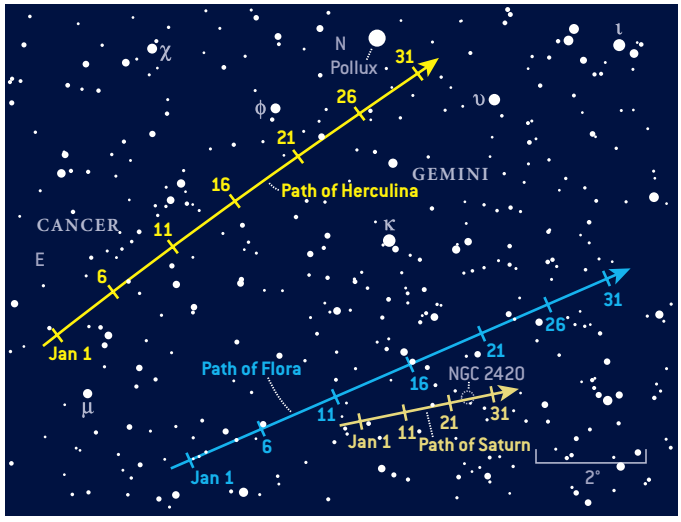
Although the meeting with the Pleiades will highlight the month, Comet Machholz has another intriguing rendezvous. On the nights of January 15 and 16, the comet's tails probably will obscure much of the Perseus galaxy cluster, which is centered on NGC 1275.

Pollux's pair

With telescopes now pointing toward Saturn, it's easy for asteroid hunters to hop over to two nice targets. Sometime between January 15 and 20, slide 1° (about two lunar diameters) due north of the ringed planet. There, the eighth asteroid to be discovered, Flora, glows at magnitude 8.5. Use the finder chart to locate it on other nights.

The high-numbered rock 532 Herculina passes 1° south of Pollux at the end of January. Spanning 129 miles (207 km), Herculina is considerably bigger than Flora's 86-mile (138 km) diameter. The main reason Herculina glows a little fainter (at magnitude 8.9) than Flora is that it lies farther from Earth, but it also reflects about 5 percent less light.

With the profusion of Milky Way stars in the background, the asteroids will be camouflaged. A good way to identify them is by detecting their telltale motion across the sky. On the night of January 23, each asteroid will pass south of its own 7th-magnitude field star. Use another field star to anchor your sketch, then come back in about 3 hours to see that the asteroids have moved. You'll have to wait until mid-evening for them to rise well above the eastern horizon.



Lucifer's planets

Three newly discovered, low-mass worlds could be rocky super-Earths — and among the strangest planets yet.

/// BY RAY VILLARD ///

The search for extrasolar planets has crossed a key threshold. In August, three teams of astronomers announced the discovery of three extrasolar planets small enough that they could be made primarily of rock and metal. All previous planets found circling normal stars are probably gaseous. The new planets' masses fall roughly between 15 and 20 Earth masses, putting them in the same ballpark as Neptune. They all whirl around their stars within a few days at a fraction of Mercury's distance from our Sun.

Although the discovery of these planets made big news, one aspect garnered little publicity: If these worlds are rocky, they are among the most bizarre and surprising planets found so far. Even among exoplanet experts, who have learned to expect the unexpected in the diversity of alien worlds, these places are baffling. They make craggy, Sun-baked Mercury look comparatively temperate. At least one of the new planets is hot enough to have a surface of bubbling lava.

Michel Mayor of the Geneva Observatory and his colleagues targeted Mu Arae, a solar-type star located 50 light-years away in the southern constellation Ara. By measuring a slight wobble in the radial velocity of the star — which reflects the gravitational pull of an

orbiting planet — they deduced the presence of a planet with at least 14 times Earth's mass that takes 9.5 days to complete one revolution. This is the second planet discovered around Mu Arae.

Paul Butler of the Carnegie Institution of Washington and Geoffrey Marcy of the University of California at Berkeley used the same technique to discover a planet circling Gliese 436, a small star located 33 light-years away in the constellation Leo. The planet orbits the star every 2.64 days at a distance of 2.6 million miles and has a minimum mass of 21 Earths. Gliese 436 possesses just four-tenths the mass of our Sun, and this planet is only the third known to orbit an M-class dwarf star.

The third new planet also revealed its presence through a tiny wobble in the radial velocity of its parent, the solar-type star 55 Cancri. Barbara McArthur of the University of Texas at Austin and her coinvestigators found a planet that whips around 55 Cancri every 2.81 days at a distance of 3.5 million miles — merely one-tenth Mercury's distance from the Sun. Three gas-giant planets also revolve around this star, located 41 light-years from Earth in the constellation Cancer, with periods

A POSSIBLE SUPER-EARTH lurks close to the Sun-like star 55 Cancri. This world is one of the smallest extrasolar planets discovered to date — and quite possibly one of the most bizarre. ADOLF SCHALLER

of 15, 44, and 4,520 days. McArthur's team also observed the system with the Hubble Space Telescope to determine the star's wobble on the sky. Combining this with the radial-velocity measurements gives the orbital inclination of the planets and a fairly precise mass estimate for the new planet: 18 Earths.

On the trail of Earths

Since the first extrasolar planets were discovered nearly a decade ago, improvements in planet-detection techniques have brought astronomers ever closer to finding Earth-mass worlds in Earth-like orbits — the most exciting worlds because they would be most likely to harbor life. Predictably, the more massive planets popped up first because they exert a greater pull on their parent stars and so produce larger wobbles in the stars' motions. The recent discoveries bring the mass range for extrasolar planets down to the size of Neptune, or perhaps Uranus.

No observational evidence shows whether these new planets are super-Earths or more akin to Uranus and Neptune. If any of the planets was seen transiting its star, astronomers would know — a puffy gas giant would block more starlight than a ball of rock.

It's reasonable to expect "star-hugger" super-Earths to lurk among the Milky Way's stars. A star-hugger is a planet that migrates close to its star and then, somehow, its orbit stops shrinking just before it falls into the star. Many of the known exoplanets have been dubbed "hot Jupiters" because they are gas giants that lie close to their parent stars. Whether or not these new planets are solid or gaseous, it's likely that "hot rocks" exist somewhere in our galaxy.

A super-Earth orbiting close to its star presents a stark and baffling picture that leaves planetary scientists in awe. "It would not be hard to just scale-up an earthlike rock to that size and predict its thermal history," says Mark Richards of the University of California at Berkeley. "But my good sense tells me that would probably be an empty exercise without putting a lot of thought into how such a planet might evolve in a fashion that is qualitatively different from Earth." Greg Laughlin of the University of California at Santa Cruz adds, "We're currently trying to understand more about how these types of objects would behave. If I were to speculate right now, I would envision a nasty, high-mass version of Venus."

A fully baked world

The most intriguing of the newly discovered worlds has to be the one orbiting 55 Cancri. It certainly ranks as the most extreme. Located just 3.5 million miles above the star's seething photosphere, a rocky planet would have an ocean of liquid magma on its sunlit side. Call it the Lucifer planet. (Coincidentally, the Romans called Venus "Lucifer" when it appeared in the morning sky. It makes an apt name for this new planet, whose sunlit surface would be as hot as a lightbulb filament.) Depending on how cool the crust is on the planet's shadowed farside, sluggish waves of lava, creeping under a pull twice that of Earth's gravity, would slosh up to frozen basaltic shores near the boundary between day and night.

As if the stellar radiation isn't bad enough, a rocky world of 18 Earth masses also would be seething from the inside. Such a world would have a core of radioactive elements perhaps 30 times bigger than Earth's because its parent star has about twice the fraction of heavy elements as the Sun. But the planet's radius would be only three times that of Earth's, yielding a surface area for radiating heat only about 10 times that of our planet. Aside from being baked from the outside, the

OCEANS OF MOLTEN LAVA lap against a distant shore on the starlit side of the possible super-Earth orbiting 55 Cancri. Such a planet's dark side likely would feature continents of solid crust floating on a magma sea. ADOLF SCHALLER

planet would have a lot of trapped heat to vent. Radar mapping of cloudy Venus by the Magellan spacecraft gives us a preview of what the dark side of our Lucifer planet might look like (although Magellan did not record active volcanism). Just imagine molten rock pouring from immense but shallow volcanic calderas, creeping across the nighttime surface like a luminous monster stretching its tentacles. There also could be oozing pancake domes, lava channels, sinuous rilles, and rolling volcanic plains.

The interior of the planet might be so hot that the dark-side crust would float on molten rock — a fiery analogue to the ice rafts floating on Europa's subsurface ocean. These possibly continent-size rafts might drift onto the planet's sunlit side, where they would melt like pats of butter left on a sunny picnic table. New volcanic material upwelling on the planet's farside would cool and make new crust, keeping the conveyor belt going.

Gravity might tidally lock Lucifer to its star, forcing the planet to keep one hemisphere pointed permanently toward the star just as our Moon keeps one face toward Earth. However, the only planet we know where tides have drastically slowed its spin is Mercury. And it is *not* in synchronous rotation but instead spins three times every two orbits. The situation would get even more complicated if the steamy, starlit side of the Lucifer planet loses mass into space. This would shift the planet's center of gravity and keep it from being tidally locked. So it could have a bizarre wobble or rotation that exposes the entire surface to 55 Cancri over time.

Regardless of tidal lock, the whole planet simply may be a ball of plastic mush. "The best guess would be to look at the speculations regarding geology on the Archean Earth," says Jonathan Lunine of the University of Arizona, "when heat flowed through the surface at a much higher rate than today. And I don't think the geologic style cares much about whether it is night-side or day-side."

Laughlin points out that two relatively nearby gas-giant planets also pull on the overheated planet. This would make it an aggressive, distant cousin of Jupiter's moon Io. The gravitational tug of Jupiter's large satellites pumps energy into Io, driving continuous volcanism. Likewise, because the 55 Cancri system contains a Jupiter-mass planet 11 million miles from the star and a second one 22 million miles out, the gravitational tug-of-war with these giants would heat the planet's already molten interior even further.

Under twice the pull of gravity, you might expect the planet to hold onto a dense atmosphere that could help warm the dark side. Withering, superheated gales would blow from the molten side to the cold trap on the farside. "A planet that massive ought to keep its carbon dioxide atmosphere, with the proviso that proximity to the star will yield high photolysis [breakdown of molecules by light] and hence escape rates of the atoms," says Lunine.

The view from up close

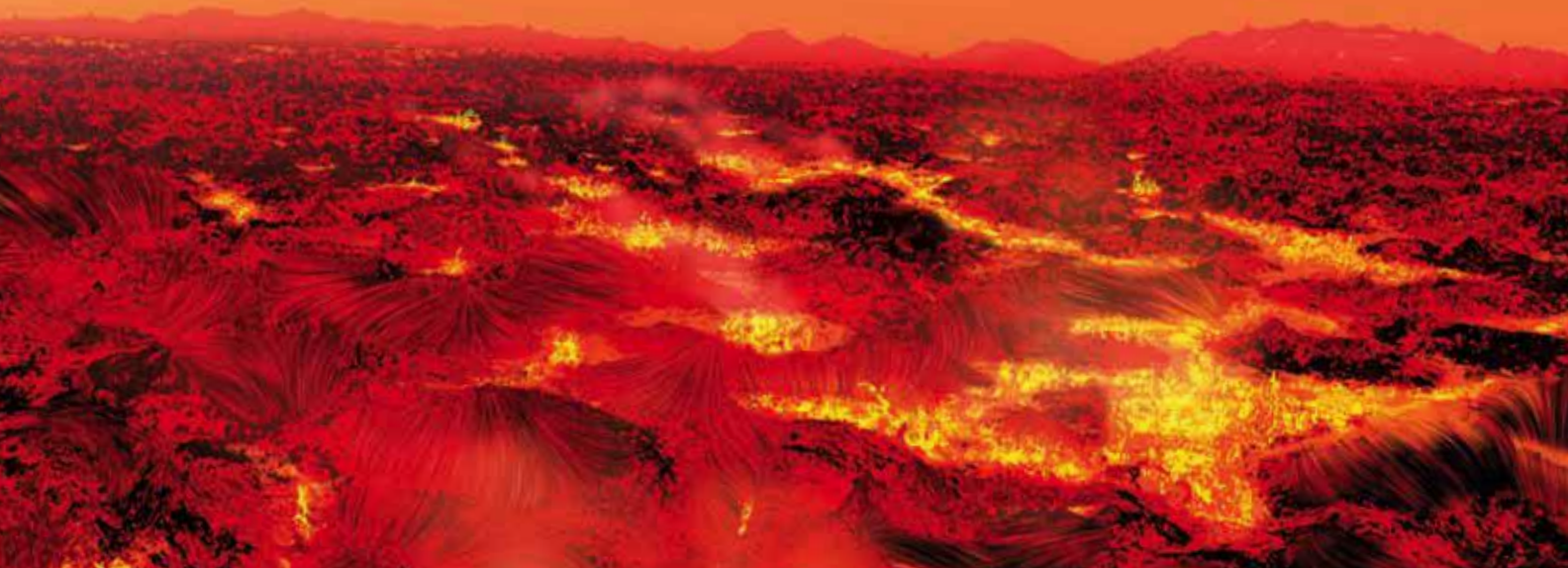
Even more enticing than the nature of 55 Cancri's potential super-Earth is the possibility this star might be one of the nearest with one or more inhabited planets. There's room for terrestrial planets to be distributed between the set of three inner planets and the outermost giant, which orbits nearly 500 million miles from the star — about Jupiter's distance from the Sun. Because 55 Cancri is as old as the Sun, planets would have had enough time for intelligent life to evolve (assuming Earth is a rule rather than an exception).

Alien astronomers living on an earthlike world embedded in this bizarre system would have a field day. The brilliant giant planets would have been known about since antiquity. The concepts of a heliocentric system would have developed quickly as early skywatchers followed the motions and phases of the two inner giants. But the innermost Lucifer planet lies too close to the star to be seen visually from an earthlike distance. Perturbations in the orbits of the other two giant inferior planets, however, surely would lead Cancrean astronomers to predict the presence of the third, innermost body. Their solar astronomers likely would stumble upon the planet directly by catching a fleeting transit across the face of their star.

Whether anyone lives there or not, the 55 Cancri system would have to be a top contender for a visit from an unmanned interstellar probe dispatched from Earth in the far future. Streaking across the system at a significant fraction of the speed of light, the probe's last duty — after examining the three known gas giants — might be to fall near the star to image the Lucifer planet. This is one extremely strange place that scientists would love to see up close and personal. It almost certainly will remain beyond the reach of the most powerful Earth-based telescopes imagined.

Ray Villard *is the public information officer at the Space Telescope Science Institute in Baltimore. His most recent article for* Astronomy *was "Beyond Hubble" in the October 2004 issue.*

Find out the basics about the known extrasolar planets at www.astronomy.com/toc



ASK ASTRO

Using Cepheids, many moons, impending supernova

USING CEPHEIDS

How do astronomers use Cepheid luminosities to calculate distances? — ERNI HALAXA, DUBLIN, CALIFORNIA

Cepheid distances are determined through the so-called inverse-square law of light, which tells astronomers how a star's apparent brightness diminishes with distance. If a star appears to have a certain brightness at some given distance, then it will appear 4 times fainter at twice that distance, 9 times fainter at triple that distance, and so on.

Conversely, if you know the intrinsic brightness of a star and measure its apparent brightness, you can determine its distance. Expressed in mathematical terms, the relationship is

$$\log d = 0.2\,(m - M + 5)$$

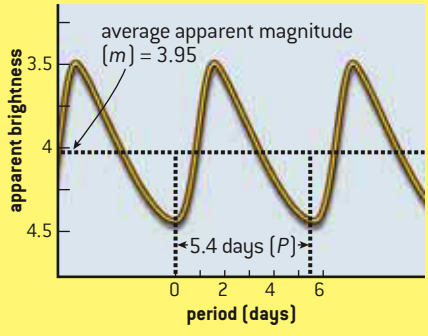
where d is the distance of the star in units called parsecs (1 parsec is 3.26 light-years), m is the measured brightness of the star in magnitudes, and M is the star's intrinsic brightness in magnitudes, formally called its absolute magnitude.

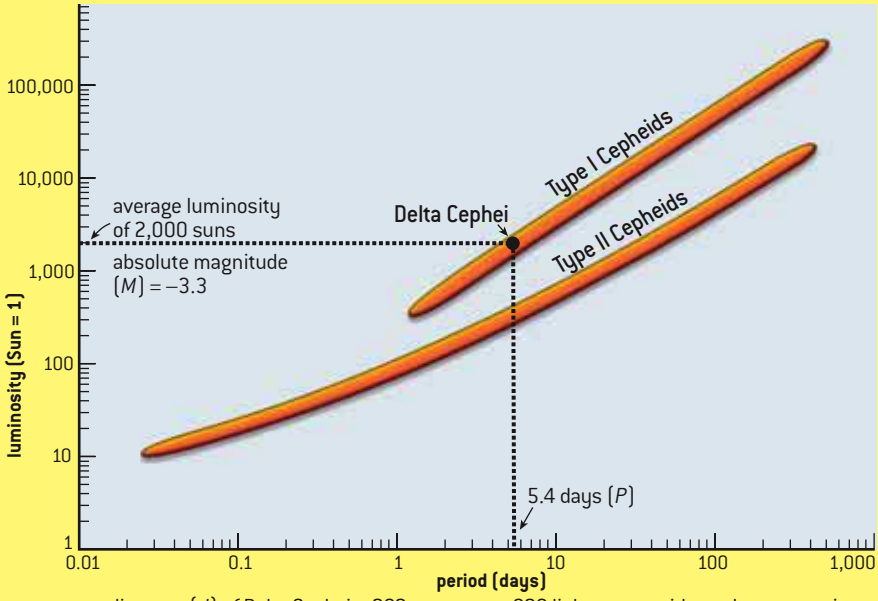
Usually, the problem in applying this formula lies in how we determine absolute magnitude, and it is here that Cepheids shine. These pulsating stars expand and contract with periods ranging from roughly 1 day to more than 50 days. Fortunately, a few Cepheids are members of star clusters, for which astronomers can derive distances by other means. These cluster Cepheids inform us that their pulsation periods (P) and absolute magnitudes share a mathematical relathionship:

$$M = -2.9 \log P - 1.2$$

A Cepheid changes its brightness throughout its pulsation cycle, so astronomers find the value of P by measuring the star's apparent brightness through one full cycle. Values for absolute and apparent magnitudes are averages over the pulsation cycle. Plugging them into the first equation allows astronomers to determine the distance to the star.

There are, of course, a few caveats. First, the numbers in the second equation relate to magnitudes measured through a yellow filter; using blue or red magnitudes alters the numbers. Second, Cepheids are generally so far away that we view them through a considerable amount of interstellar dust, which makes them look fainter and redder than they really are, and astronomers must correct for this. Third, there are two groups of Cepheids, each with slightly different period-luminosity relationships. — J. DONALD FERNIE, UNIVERSITY OF TORONTO (ONTARIO)





CEPHEIDS FORM A VITAL LINK in the chain of methods used to determine cosmic distances. Delta Cephei, a Type I Cepheid and archetype of the class, changes brightness in a 5.4-day cycle. This period means the star must be about 2,000 times more luminous than our Sun. Comparing the star's luminosity to its observed brightness yields a distance of about 920 light-years. After accounting for dimming by dust, astronomers place Delta Cephei a little closer, about 815 light-years away.

distance (d) of Delta Cephei = 282 parsecs, or 920 light-years, without dust correction
250 parsecs, or 815 light-years, with dust correction

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live.

MANY MOONS

Would you name the Full Moons of the year and explain each name? — ROBERT W. BEKECH, WESTFIELD, MASSACHUSETTS

We've all heard of the Harvest Moon and the Hunter's Moon but probably not the Green Corn Moon. Various cultures have their own nicknames for each Full Moon, but many of those used in North America — and which we'll consider here — come from Native Americans. These names are easy to remember because people assigned them based on what was then happening in the natural world. Here's a brief list:

January: Wolf Moon. This is the month when wolf packs roam, howling and looking for food. It's also sometimes called Old Moon and After-Yule Moon.

February: Snow Moon. Inhabitants of the Northern Hemisphere usually see the worst snows during this month. It's also known as Hunger Moon and Storm Moon for the same reason.

March: Worm Moon. Warming soil in March brings worms to the surface. The March Full Moon also is called Crow Moon, Crust Moon, Sap Moon, Sugar Moon, and Chaste Moon.

April: Pink Moon. This name is a reference to the bright blossoms of wild phlox beginning to bloom in April. It's also called Seed Moon, Sprouting Grass Moon, Egg Moon, and Fish Moon.

May: Flower Moon. April showers bring May flowers, but this Full Moon also is known as Hare Moon, Corn Planting Moon, and Milk Moon.

June: Strawberry Moon. Wild strawberries are ready for picking in June. Alternative names are Rose Moon, Dyad Moon, and Hot Moon.

July: Buck Moon. This is the month when young bucks begin to sprout antlers. It's also called Mead Moon, Thunder Moon, Hay Moon, Sturgeon Moon, Red Moon, and Green Corn Moon.

August: Barley Moon. Barley and other grains, as well as many fruits, are ready to harvest in August. Sturgeon Moon, Grain Moon, and Red Moon are also names for August's Full Moon.

September: Harvest Moon. Almost all native crops, such as rice, squash, corn, beans, and pumpkins, are ready to harvest this month. Because of the timing of sunset and moonrise, September's Full Moon provides a nightlight that lets farmers work late into the evening. It's also called Corn Moon.

October: Hunter's Moon. Animals have eaten well all summer, and in October they are ready to be hunted for the winter meat supply. The timing of sunset and moonrise gives an advantage to Northern Hemisphere hunters, who can now track their prey well into the night. This month's Full Moon also is called Blood Moon, Travel Moon, and Dying Grass Moon.

November: Beaver Moon. Beavers are active before the hard winter cold sets in. The animals' warm fur makes beaver pelts a sought-after item. November's Full Moon also is called Frosty Moon.

December: Long Nights Moon. The Sun makes its lowest arc through the Northern Hemisphere sky during December, which is why this month's nights are the longest of the year. December's Full Moon also is known as Cold Moon, Oak Moon, and Before-Yule Moon. — **BRENDA CULBERTSON,** CRANE OBSERVATORY, WASHBURN UNIVERSITY, TOPEKA, KANSAS

A SHATTERED STAR SHINES ON, emitting X rays (blue) and heat (red, green). Supernova remnant W49B, the subject of this composite view, lies some 35,000 light-years away in Aquila. NASA/CXC/SSC

IMPENDING SUPERNOVA

If we lived on a planet circling a star about to go supernova, would we know it was going to happen? — DEE SHARPLES, HONEOYE FALLS, NEW YORK

There is no clear answer. The seeds of catastrophe that will destroy a star in a supernova are buried deep in the star's heart, but all we can see easily is the surface, buffered by the stellar mass in between. There were images of SK –69°202, the star that blew up as SN 1987A, but no clue in those images of an impending eruption.

However, with proper technology and a heartfelt desire to save one's civilization, there are ways to detect changes deep within a star. In particular, there should be quantitative changes in the neutrino flux associated with nuclear reactions that signal the onset of rapid burning or collapse.

These neutrinos have low energies and would be difficult to detect, but being next door would help. Another possibility is that the star's deep nuclear burning would be convective, and the resulting roiling motions would make waves that might propagate to the stellar surface. Proper diagnostics might expose the star's inner workings from all the commotion on its surface, like spots and flares. — **J. CRAIG WHEELER,** UNIVERSITY OF TEXAS AT AUSTIN

This tiny, dipper-shaped cluster of stars has intrigued humans for thousands of years. /// BY RAYMOND SHUBINSKI

Lure of the Pleiades

On the evening of October 19, 1859, lithographer Ernst Wilhelm Leberecht Tempel (1821–1889) set up his 4-inch refractor on the balcony of a Venetian palace for a night of observing. He'd moved from Saxony (part of modern Germany) to Italy to practice his trade but found himself drawn to astronomy. On this night, as the waning gibbous Moon rose in the east,

Tempel turned his telescope on the well-known cluster of the Seven Sisters, the Pleiades. As he studied the area around the bright star Merope, he noticed a smudge of light, a nebula. Other astronomers were unconvinced, but the nebula was soon confirmed by many observers.

Almost a century earlier, the great comet hunter Charles Messier added the Pleiades to his growing list of objects as number 45. Messier included this cluster more to cap off his list than as a warning to future comet seekers. Messier made no mention of nebulosity in this region. Not until 1885, when the first Pleiades photos were taken, was the true glory of this cluster revealed.

The power of myth

These data tend to blur the impact the Pleiades has had on humans across the globe and through time. The myth and mystery that surround the Seven Sisters are as beautiful as the reflection nebula that surrounds the stars.

In the age of myth, the giant Orion fell in love with the daughters of Atlas and Pleione. The young women were Alcyone, Merope, Celaeno, Taygeta, Sterope, Electra, and Maia. Orion's advances repulsed the girls, but he was persistent. To save the young women, Zeus turned them into doves, which flew up to heaven for safety.

The legend of Zeus and the Seven Sisters is one of many early references to this cluster. Chinese records of its sighting date to 2350 B.C., while the Greek historian Hesiod mentions the Pleiades around 700 B.C. in his work *The Astronomy*. He refers to the group as "the stormy Pleiades." In his *Works and Days*, Hesiod admonishes his readers: "When you notice that the Pleiades and the Hyades and the strength of Orion are setting, then it is the time for you to be mindful of plowing again."

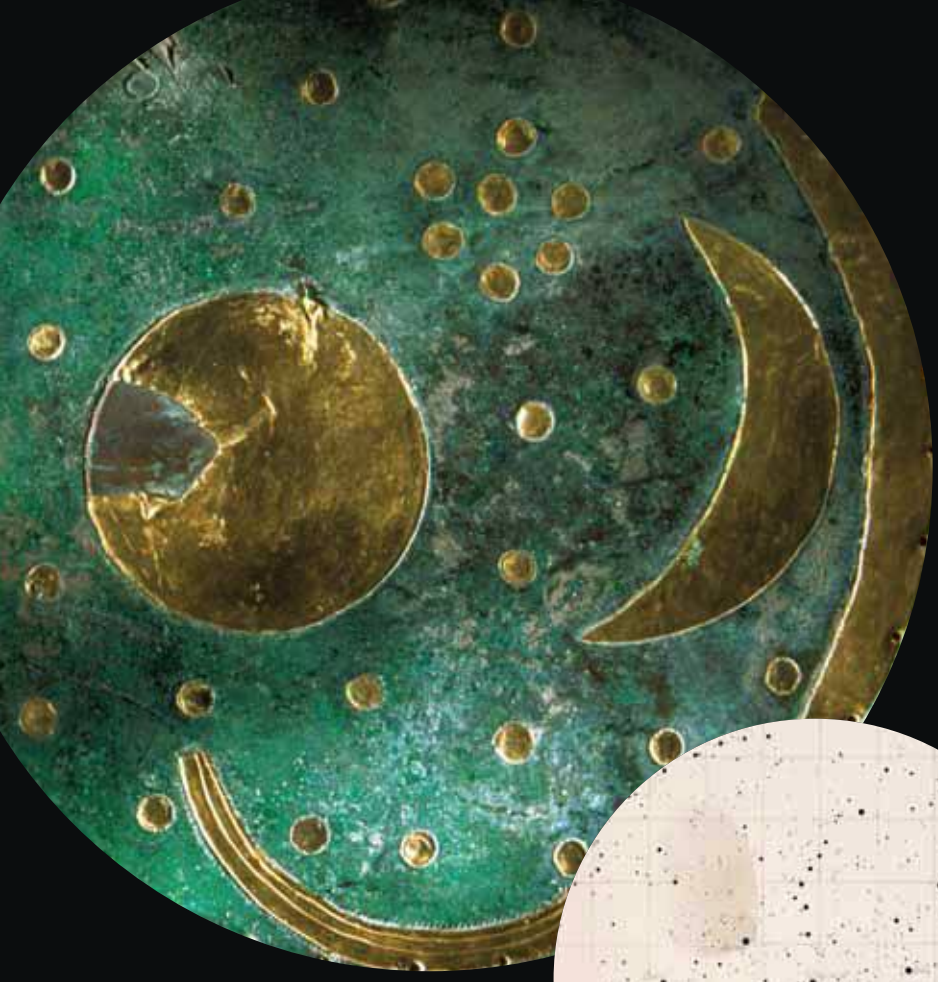
Interest in the Pleiades may go even further back in time. A Bronze-Age artifact was uncovered by looters in Germany sometime in the 1990s. It is known as the Nebra Sky Disk and has caused great excitement in both archaeology and astronomy. The bronze disk measures about 12½" (32 centimeters) in diameter and dates to about 1600 B.C. Gold inlays appear to represent the Full and crescent Moon. The Sky Disk also pictures a "Sun ship," random stars, and a grouping of seven gold stars that may represent the Pleiades. If this interpretation is correct, the Nebra Sky Disk may be the oldest "pocket" sky chart in existence. This also means ancient skywatchers began using the Pleiades as a calendar indicator almost 900 years before Hesiod wrote his poetic almanac.

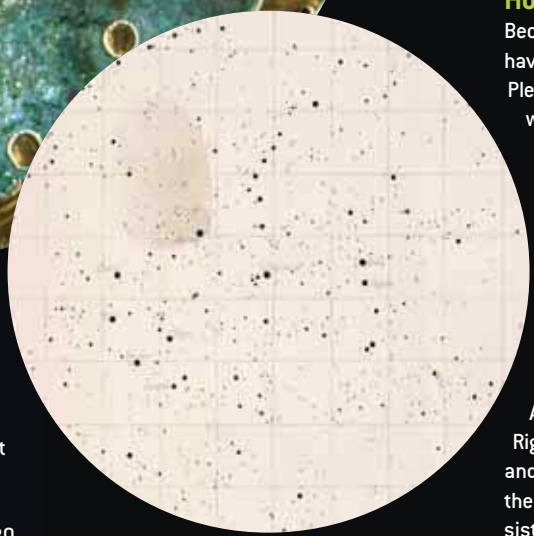
The Pleiades lies within 4° of the ecliptic in the constellation Taurus the Bull. The bright cluster can be seen easily from all of the Northern Hemisphere and most of the Southern. Garrett P. Serviss (1851–1929), in his 1888 classic, *Astronomy with an Opera-Glass*, says, "In every age and in every country the Pleiades have been watched, admired, and wondered at, for they are visible from every inhabited land on the globe."

For countless millennia, the aboriginal people of Australia lived under a night sky darker and richer in stars than most of us can imagine. Thousands of years ago, in what was called the "dream time," these people would have seen the Pleiades passing high in the south shortly after sunset in early December. As they sat about their fires, they told stories of seven women who — as in the Greek myth — a brute of a man had taken a fancy to and given pursuit. In this case,

Raymond Shubinski — *an admirer of the Pleiades — is the director of the East Kentucky Science Center in Prestonsburg, Kentucky.*

NASA/AURA AND ESA/CALTECH





THE NEBRA SKY DISK (above) dates from about 1600 B.C. The seven dots in the upper center may represent the Pleiades. KENNETH GARRETT/NATIONAL GEOGRAPHIC IMAGE COLLECTION

THE MEROPE NEBULA was discovered by Ernst Tempel October 19, 1859. His sketch (right) appeared in the *Monthly Notices of the Royal Astronomical Society*, vol. 40, Supplement 1880. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, & TECHNOLOGY

THE CLUSTER OF SIX POINTS above the bull may represent the Pleiades. If so, this is the earliest representation that still exists, dating from about 15,000 B.C. This cave drawing is in the Salle des Taureaux, Grotte de Lascaux, France. DAVID WHITEHOUSE

the man was represented by one of the bright stars in Orion's Belt. To escape, the seven women were turned into fire and rose up into the sky. The chase continues, with the stars of Orion's Belt always nearby. A modern aboriginal artist, Norah Napaljarri Nelson, depicted this ancient story in a 1991 painting that represents a revival in aboriginal art.

It's amazing that so many cultures saw this group of stars as seven young women. The Kiowa Indians tell a story of seven maidens that were being chased by a giant grizzly bear. As the maidens ran across the plains to escape this monster, the gods raised a tower of rock to protect the young women. The bear clawed furiously at the rock in an effort to reach the women, but they ran into the sky, where they are seen as the Pleiades. The clawed mountain in the story is now known as Devil's Tower in Wyoming.

How many sisters?

Because of light pollution, many city-dwellers have problems seeing three or four stars in the Pleiades. From a dark site, however, observers with good eyesight can spot more than the six stars most people see. Johannes Kepler claimed to have seen 14 stars in the Pleiades and plotted the positions of 11 of them. This came from a man who asked to be excused from the observing duties set for him by Tycho Brahe because of his poor eyesight!

Alcyone is the brightest star in the cluster at magnitude 2.9. Next in brightness is Atlas, the father of these young ladies, at 3.6. Right behind Atlas are Electra and Maia at 3.7 and 3.9, respectively. Merope, associated with the most easily seen nebulosity, is 4.2, while her sister Taygeta comes in at 4.3. The mother of this starry clan is Pleione, which can be found just above Atlas. Pleione is a variable star that fluctuates from magnitude 4.8 to 5.5. The remaining two sisters are Celaeno at 5.4 and Sterope (or, Asterope), also a variable star that ranges from 5.6 to 6.4. All these are hot, blue stars spinning at high speeds. They rotate so fast they've been flattened into oblate spheroids. Pleione is rotating so rapidly it has ejected a gas shell off its surface.

As Serviss also points out in *Astronomy with an Opera-Glass*, it's odd that ancient skywatchers wrote only six stars were easily visible. As many acute observers have shown, the nine named stars — and perhaps more — can be seen under the right conditions. Because it's easiest to see the brightest six stars, several cultures had stories of a "missing" Pleiad.

The Kiowa Indians thought one star never made the trip to the sky. The Greeks had several stories about the hard-to-see sister. One such story relates that Electra covered her face at the sight of the beautiful city of Troy burning at the end of the Trojan War. Another variation says

Merope wed a mortal and hid herself in shame. Because of the pervasive nature of the "lost" Pleiad in so many cultures, Robert Burnham, writing in *Burnham's Celestial Handbook*, suggested the brightness fluctuations of the variable star Pleione may hold the key to this recurrence. Some historians suggest ancient peoples had a preference for the number seven, but this still skirts the issue of unrelated cultures telling stories of a missing star. Indeed, the explanation simply may be a combination of how good the observer's eyes were and widely variable sky conditions in different parts of the world.

Space clouds

This cluster has been associated with cosmic clouds since the first Pleiades photographs were taken. The nebulous gas in which the cluster appears led astronomers to speculate that the Pleiades is a young star cluster still emerging from its birth cocoon. The interaction between the cluster and the nebulosity turns out to be more complicated than expected. The Pleiades is, in fact, a young open cluster, but the gas clouds do not represent "leftover" material from the stars' formation.

Conditions in the Pleiades region are fantastic. The giant blue stars produce strong stellar winds, which have interesting effects on the surrounding gases. American astronomer Edward Emerson Barnard (1857–1923) noticed another bright nebula near the star Merope in 1890. It became known as "Barnard's Merope Nebula" (to distinguish it from the one discovered by Tempel) and was cataloged as IC 349. In September 1999, astronomers George Herbig and Theodore Simons of the University of Hawaii used the Hubble Space Telescope to obtain a ghostly image of IC 349. As the nebulosity drifts toward Merope, radiation pressure from Merope slows the smaller dust particles. The results are dramatic, making the area look like wheat chaff thrown into the air during winnowing.

Richard White, professor emeritus of Smith College in Northampton, Massachusetts, has had a long-term interest in the Pleiades. While in graduate school at Columbia University in New York City, he studied the gas clouds that surround the Pleiades.

From the radial velocities of the gas clouds, White knew the nebulosity was unrelated to the stars. When he read the results of Herbig and Simons's studies of IC 349, however, he was amazed to find the "drift" of IC 349 was different than his earlier results in both speed and direction. Something else was going on.

Measurements of the main stars in the Pleiades indicate the cluster is moving away from us at 10,800 miles (17,400 kilometers) per hour. The motion of the gas clouds also was studied using spectral analysis, which showed the stars are moving through the nebula. In a collaborative effort between students from Smith College and Amherst College in Massachusetts, a new picture of cosmic interaction emerged. White now describes the area of the Pleiades as a three-way "demolition derby." Arriving at this conclusion was no easy task.

The gas clouds near the hot stars of the Pleiades scatter starlight, creating a glow like a streetlamp in fog, but the spectra of the stars and the nebulae still needed to be separated to determine their relative motions. When the Smith-Amherst team did this, it found not one, but two sets of interacting clouds, and neither is related to the nearby stars. According to White, "This interaction makes the Pleiades altogether unique as a natural laboratory." It may seem mundane for a professional astronomer to put so much effort into such a familiar celestial object. When asked what he studies, however, White enjoys pointing to the Pleiades — something you can easily see.

Poetic ending

The Pleiades exerts a special hold over astronomers and poets alike. Twenty-first-century astronomers continue to learn about the Pleiades, and literature reflects our fascination with this star cluster. Perhaps Alfred Lord Tennyson penned the most famous lines about these stars in "Locksley Hall":

Many a night I saw the Pleiads,
Rising thro' the mellow shade,
Glitter like a swarm of fire-flies
tangled in a silver braid.

The 13th-century Persian poet Sadi of Shiraz also wrote about the Pleiades. In *The Rose Garden*, he said, "The ground was as strewn with colored enamel, and necklace of Pleiades seemed to hang upon the branches of trees."

The drama and call of the Pleiades have been felt in many ways. In 1905, 5-year-old Leslie C. Peltier, who became one of the greatest observers of variable stars, stood in the dark kitchen of his Ohio farmhouse and asked his mother the name of the small cluster of stars visible through the window. "Those are the Seven Sisters. Sometimes they are called the Pleiades," replied his mother. Peltier heard the silent song of the Pleiades and, for the rest of his life, heeded their call.

Robert Louis Stevenson wrote about the stars in *Travels with a Donkey*, first published in 1879. Stevenson said a person "may know all their names and distance and magnitudes, and yet be ignorant of what alone concerns mankind — their serene and gladsome influence on the mind. The greater part of poetry is about the stars; and justly, for they are themselves the most classical of poets."

For more images of the Pleiades, visit www.astronomy.com/toc

/// PLEIADES FACT SHEET

GEORGE GREANEY

Type of object: Open cluster

Position: R.A. 3h47m, Dec. 24°07'

Apparent size: 2°

True size: 25 light-years in diameter

Number of stars: 300 to 500

Age: 20 million years

Distance from Earth: 434 to 446 light-years

Designations: Pleiades, Seven Sisters, M45, Melotte 22, C 0344+239, H 0346+24, OCl 421.0

Interesting facts: If the light from the Pleiades were emitted by a single star, that star would shine at magnitude 1.6, or about as bright as Castor (Alpha [α] Geminorum). M45 is the brightest open cluster we can see from Earth and the closest of all the Messier objects. The Pleiades does not possess a number in the NGC catalog. Several early celestial cartographers, among them the Greeks Aratos and Eudoxus, listed the Pleiades as a separate constellation.

THE NAMES OF THE STARS in the Pleiades come to us directly from Greek mythology. Seven of the names — Alcyone, Merope, Celaeno, Taygeta, Sterope, Electra, and Maia — represent the sisters. The other two star names — Atlas and Pleione — are the sisters' parents. *ASTRONOMY:* ROEN KELLY

Observing the Sun through Hα filters has been expensive — and often frustrating — for amateur astronomers. Now, that has changed. /// BY JEFF MEDKEFF

Coronado's Personal Solar Telescope

I've been a hydrogen-alpha (Hα) junkie since my first look through such a filter 21 years ago. I still remember my first view of prominences protruding past the limb of the Sun, filaments lying like stray hairs across its face, and bright active regions scattered around the solar atmosphere. Although I was a neophyte, I realized immediately that this was a special class of observing. Through an Hα filter, I could see a higher layer of the Sun's atmosphere and a whole new class of features — it didn't look anything like what I observed through a white-light filter.

Through the years, I stole looks through dozens of Hα filters and even owned a few. I quickly learned that the slimmer the filter's bandwidth — the little slice of the solar spectrum the filter lets through — the better the view. At narrow bandwidths, around half an angstrom (Å), the Sun's disk is almost furry — an incredible forest of contrasty details jumps out, creating an image as memorable to most people as their first views of Saturn. But as the bandwidth swells, the image gets washed out. The big problem with Hα filters, however, is expense. As recently as 10 years ago, many Hα solar filters cost more than $10,000. By the time a long-focal-ratio refractor (the preferred instrument) was added, and a sturdy mount was acquired, many people had spent as much money for a solar telescope setup as they would have for a luxury automobile.

By the late 1990s, new suppliers, improved filter designs, and Hα solar telescopes that were self-contained appeared on the market. Selection and performance improved. Prices dropped, but only a little. Hydrogen-alpha observing was still expensive, but more tolerable than before. It seemed amateur solar observing might be entering a golden age. Still, nobody was prepared for an announcement that a complete Hα solar telescope soon would appear and cost only $499 including the eyepiece. Like many people, I was unprepared to believe such an inexpensive instrument could perform acceptably, until I tried one.

THE BLACK RING allows users of Coronado's PST to "tune" the image. A gentle turn reveals solar prominences; turn the ring the other way, and chromosphere detail is revealed. *ASTRONOMY*: WILLIAM ZUBACK

Coronado's PST

Coronado Technology Group's Personal Solar Telescope (PST) is a self-contained Hα solar-observing rig. The PST is a 1.6-inch refractor that has an Hα filter sealed inside. At 15" (38 centimeters) long, it is lightweight and super-portable. It accepts 1¼" eyepieces, has a small knob to control focusing (which is done internally), and sports a ring at the base of the brass tube that allows the user to "tune" the image. There is also a solar finder, which the maker calls a "Sol Ranger," built into the telescope's body.

According to the PST's manual, the worst — that is, the widest — bandwidth this filter would pass was marginally less than 1 Å (less, at times, depending on how the observer tuned it). Tuning allows for

CORONADO'S PERSONAL SOLAR TELESCOPE is ready to attach to a camera tripod right out of its case. The MALTA tabletop mount, shown here, is optional. *ASTRONOMY*: WILLIAM ZUBACK

THE PADDED CASE the PST is packed in contains spaces for everything you'll need for tabletop solar observing, in addition to protecting the contents. *ASTRONOMY:* WILLIAM ZUBACK

better views of certain parts of the solar disk. Tune the PST's filter slightly, and the chromosphere is more prominent; tune it a bit differently, and prominences will stand out. A 1 Å bandwidth is fairly wide for a solar Hα filter, and I expected the view to be disappointing. I prepared myself for washed-out images lacking detail. When I took the PST outside for a look at the Sun, I had to change my tune.

Performance

One of the PST's delights is its solar finder. When you point the PST in the general direction of the Sun, a small image of the Sun appears in a circular window of semi-transparent material near the eyepiece. When you center that image, the Sun is in the telescope's field of view. Frankly, the little finder is amazing. It contains no projecting or fragile parts, uses no power, never needs calibration, and works accurately, reliably, and straightforwardly. Solar observers have wanted something this simple and elegant for generations.

The PST offers crisp, clear images with no sign of ghosting (a faint copy or copies of the main image) and no significant scattered light in the field of view. The Sun was slightly brighter than I prefer, but not so bright that features looked washed out. The face of the Sun was rich with detail, and when I properly tuned the PST, I easily saw several prominences projecting into space.

All the basic features one would expect to see through an Hα filter were visible through the PST. I especially enjoyed watching prominences grow and dissipate in real time. Active regions generally showed the underlying sunspot if it was large, but the contrast on the disk of the Sun was still sufficient to watch fine movement of the solar atmosphere caused by shifting magnetic fields. I watched rapidly moving features by tuning the PST to compensate for Doppler shift. I did not lament the fact I wasn't using a narrower-bandwidth Hα filter, and was pleased by the view of the Sun the PST provided. I was getting the complete Hα experience — and getting it at low cost.

The PST supported magnifications up to 100x before the image became excessively fuzzy. During periods of good seeing, 70x helped reveal details not easily perceived at lower magnifications. Although I was unable to test the telescope on an optical bench, the views the PST provided and the magnification it supported gave the impression of high optical quality.

My PST included the optional MALTA tabletop mount ($109.95), a convenient accessory that travels in the same case as the telescope. The MALTA has smooth motions and works pretty well — this accessory is not a gimmick. It's the perfect height for setting the PST on the trunk of a car or a picnic table, but its short legs are not suited for deployment directly on the ground. Ultimately, I preferred mounting the PST to a photo tripod equipped with a fluid head. This arrangement offered somewhat less stability than the MALTA but put the telescope at a more convenient height and offered a bit smoother motion. Attaching the PST to a tripod is easy, thanks to a ¼-20 thread mounting hole.

With either mount, I set the PST up in less than a minute, and this convenience encouraged me to look at the Sun frequently. I found myself checking the Sun three or four times a day when the weather was clear to see if anything was going on. Taking advantage of temporary gaps on cloudy days was also rewarding. Once, I observed the Sun peeking through a clear spot close to the horizon during a light rain while a glorious rainbow shone

Jeff Medkeff *is a lifelong amateur astronomer and hydrogen-alpha addict.*

/// PRODUCT SPECIFICATIONS

Coronado Technology Group Personal Solar Telescope specifications

- 1.6-inch f/10 refractor with integral hydrogen-alpha filter
- Internal focuser
- Tripod-mounting hole with ¼-20 thread
- Built-in Sun finder
- 12.5mm (32x) Kellner eyepiece

Dimensions/weight:
15" by 2.1" by 3"/3 pounds

Retail Price:
$499

Contact information:
Coronado Technology Group
1674 South Research Loop, Suite 436
Tucson, AZ 85710
[t] 520.740.1561
[w] www.coronadofilters.com

behind me. Over the course of weeks, the PST proved to be a delight to use, and it quickly became my favorite option for viewing the Sun.

Comparing Hα scopes

Given the PST's rated bandwidth of 1 Å, I was eager to compare it with my SolarMax40, an Hα filter also manufactured by Coronado Technology Group. The SolarMax40 has a bandpass of approximately 0.7 Å. The PST's performance had surprised me up to this point, but could it stand up to a side-by-side comparison with a narrower-band filter?

As expected, the PST's image was not as contrasty and did not show as many details as the SolarMax40's image. While the PST shows prominences just as readily as other Hα filters, it does not offer as much of the Sun's surface detail, and the difference is easily noticeable. The PST's wider bandwidth means its images fall short of what can be accomplished by filters with narrower bandwidths. In terms of performance, this — not the small 40mm aperture — is the principal limitation of the PST.

Yet the PST does not disappoint. To be honest, the biggest problem I had with the PST is a pandemic affliction of solar telescopes: the lack of an eyeshade. When observing with solar telescopes, direct light from the Sun falls on both the eyepiece and the observer's face. The glare and resulting reflections off the eyepiece glass are annoying. Various jury-rigged solutions are possible but shouldn't be necessary. I suggest solar-observing equipment manufacturers consider this and build in a solution.

Bottom line

When all was said and done, I had fallen in love — or at least serious lust — with the Coronado PST. The principal compromise the PST makes is price vs. performance. It performs well, but not spectacularly. The images are good, but fall somewhere short of great, especially if you have something better to compare them with.

On the other hand, the price is low: For better images, you would nearly triple your cost. The PST is well built and rugged — I gave it several sharp raps, tipped the tripod over a few times, and threw it around in its case a bit (all unintentional, of course), and it suffered no ill effects. But perhaps the PST's strongest point is that it is undeniably convenient to use. It throws no obstacles in the way of the observer and encourages frequent observing.

The PST should be a strong contender for your first Hα solar telescope. If cost is an issue, the PST is simply unbeatable. To those with more disposable income, the PST still is compelling if convenience is considered. Taken as a whole, the PST is an undeniable winner. A

THE BLUISH-GREEN COLOR of the PST's filter shows it absorbs red hydrogen-alpha light and reflects light of other wavelengths.

ASTRONOMY: WILLIAM ZUBACK

TELESCOPE REVIEW

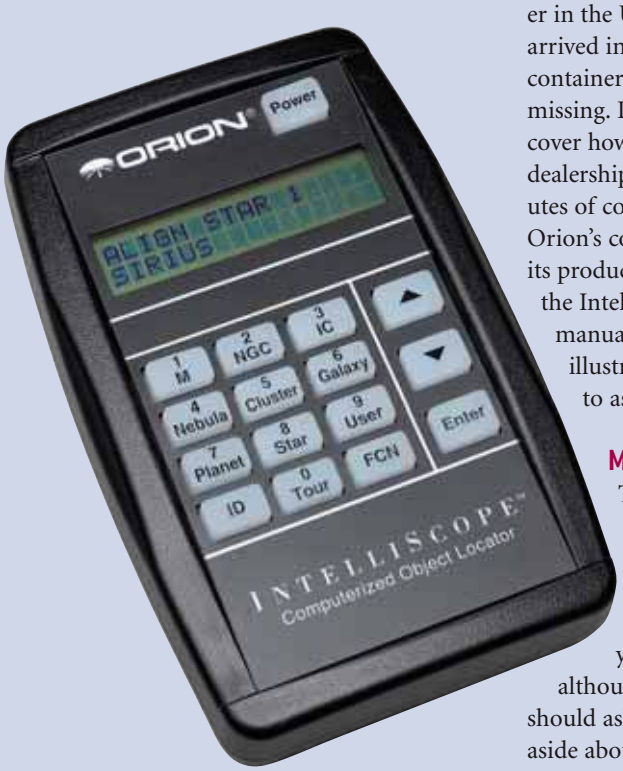
This new Dobsonian-mounted telescope offers a pleasing design, great optics, and a computer-pointing option. /// BY ADRIAN R. ASHFORD

Orion's IntelliScope XT10

I'm often asked, "What's the best telescope I can buy on a limited budget?" Usually, I recommend a Dobsonian-mounted scope. Such an instrument gives you the greatest aperture for your money without sacrificing portability. It achieves its favorable cost-to-aperture ratio by placing a high-quality Newtonian reflector tube assembly on a simple, alt-azimuth mount that's quick to set up, stable even when you choose high magnifications, and intuitive for the novice to use.

California-based Orion Telescopes & Binoculars is a company that has considerable manufacturing and sales experience with this type of instrument. Orion has a reputation for refining its products to satisfy the requirements of observers, so when advertisements appeared in 2003 for the IntelliScope — a radically redesigned version of Orion's venerable SkyQuest XT series of Dobsonians — I knew the company had done its homework.

THE COMPUTERIZED OBJECT LOCATOR (COL) is a powerful option for the IntelliScope XT10. The COL has a 14,000-object database and a back-lit control panel. *ASTRONOMY*: WILLIAM ZUBACK



Delivery

Astronomy acquired an IntelliScope XT10 from SCS Astro Ltd., a leading Orion dealer in the United Kingdom. The instrument arrived in perfect condition in two sturdy containers. Unfortunately, the manual was missing. It's times like these when you discover how well a company's international dealership network performs. Within minutes of contacting SCS Astro, I was surfing Orion's comprehensive Internet site. From its product-support pages, I downloaded the IntelliScope's 20-page manual. The manual is clearly written and profusely illustrated — a comprehensive guide to assembly, use, and upkeep.

Mount and assembly

The 26-pound (12-kilogram) mount is made of plastic-veneered particleboard in flat-pack form. If you've assembled a kitchen or bathroom cabinet, you shouldn't have any problems, although purchasers with 10 thumbs should ask a skilled friend to help. Set aside about 45 minutes for assembly.

This mount is different from a standard SkyQuest XT10's — and I'm not just talking about the integral electronics. The earlier "CorrectTension" tube-balancing springs have been replaced by a superior "disk-brake" system. Now, an adjustable lock knob causes a Teflon washer to bear against one of the 5¼-inch-wide altitude bearings. They rotate against a pair of stubby, 1-inch-wide polyethylene cylinders on either side of the mount, imparting a smooth motion to the altitude axis. Three Teflon disks mounted in routed channels on the baseboard give a similarly silky movement to the azimuth axis.

The tube

The IntelliScope XT10's tube, which is made in China to Orion's specifications and weighs 29 pounds (13 kg), is enameled, made of rolled steel, and measures 47" long and 12" in diameter. The XT10 has a focal length of 1200mm, yielding magnifications of 48x and 120x with the supplied Sirius Plössl 25mm and 10mm eyepieces. The XT10 features an excellent 9x50 finder scope with a 5° field of view. Also included is a 2" rack-and-pinion focuser featuring 1.6" of travel and an adapter for 1¼" eyepieces. An ergonomically positioned "navigation knob" permits you to slew the instrument around the sky without grasping the end of the tube.

Like the newer SkyQuest XTs, the IntelliScope uses a thin but rigid four-vane secondary-mirror holder. The elliptical secondary has a 2½-inch minor axis and is made of soda-lime glass and attached to the fully adjustable mount by a durable adhesive pad. The 10-inch f/4.7 primary mirror is made of Pyrex and center-marked for easy aligning using the supplied "collimation cap," a 1¼-inch-wide disk with a small central aperture that fits in the focuser. This simple but effective

THE INTELLISCOPE XT10 combines two seemingly disparate philosophies — a Dobsonian mount and computerized pointing. *ASTRONOMY*: WILLIAM ZUBACK

device revealed that the primary mirror was in need of a tiny amount of adjustment — something I expected after the scope's 5,500-mile (8,900-kilometer) journey from the United States.

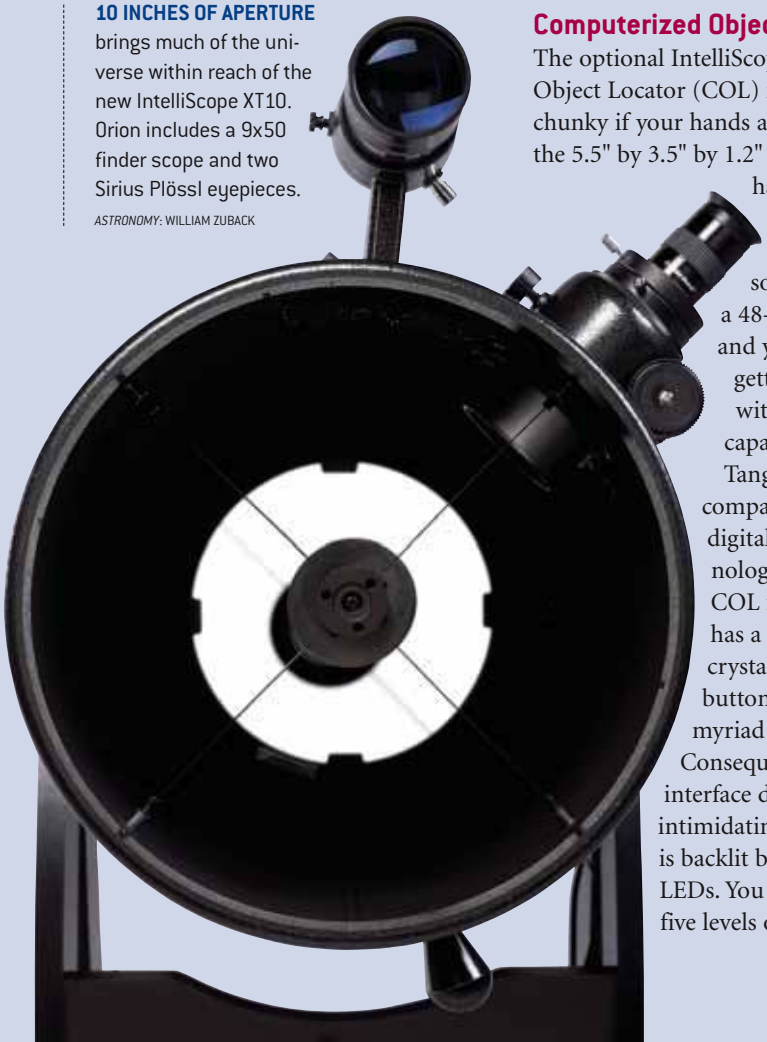
Three knurled knobs with 1.2-inch-wide chromed heads provide easy, precise adjustment of the main mirror — even while wearing gloves. To preserve collimation, Orion provides three ⅜-inch lock-down knobs. Each has a slotted head for a screwdriver but also may be tightened by hand. Four clips hold the primary mirror in a well-ventilated cell.

Optical quality

I was able to put the instrument through its paces on a wide variety of objects during a mild English winter. The exposed (although dew-shielded) secondary and the low-expansion primary mirrors allowed the XT10 to cool quickly. Star images were acceptable after 20 minutes, although the best views came after 40 minutes. After conducting several more optical tests, I have to say the XT10 possesses the best mass-produced Newtonian optics I have seen. I noticed just a trace of undercorrection in the mirror's paraboloidal figure. Otherwise, the optics were smoothly polished and showed no sign of "pinching," or astigmatism.

Indeed, the planetary views were impressive. With Jupiter and Saturn riding high in the sky and close to opposition, the XT10 delivered finely detailed views of these gas giants. In the early hours of January 14, 2004, under very steady seeing, Jupiter's cloud belts were adorned with a mass of fine spots and whorls during a shadow transit of Io. The shadow of this innermost Galilean moon was a clean, black disk against the jovian cloud tops, while the Great Red Spot, although pale, was immediately obvious through the 10mm eyepiece.

Because the supplied eyepieces are multicoated, they revealed Saturn's inner moons as tiny pinpricks of light and not swamped by the planet's glare — testament to the contrast of the Sirius Plössls. As for the XT10's performance on deep-sky objects, I thought it high time to forsake my usual star-hopping technique in favor of something more high-tech.



10 INCHES OF APERTURE brings much of the universe within reach of the new IntelliScope XT10. Orion includes a 9x50 finder scope and two Sirius Plössl eyepieces.

ASTRONOMY: WILLIAM ZUBACK

Computerized Object Locator

The optional IntelliScope Computerized Object Locator (COL) might be a bit chunky if your hands are small. However, the 5.5" by 3.5" by 1.2" rounded case of the handset and its 10-ounce weight give it a reassuringly solid feel. Add to that a 48-page user manual, and you know you're getting a telescope with some serious capabilities.

Tangent Instruments, a company respected for digital-setting-circle technology, manufactures the COL for Orion. The unit has a two-line liquid-crystal display and just 16 buttons to perform its myriad functions. Consequently, the user-interface doesn't appear intimidating. The COL's panel is backlit by green and/or red LEDs. You can choose from five levels of illumination.

/// PRODUCT SPECIFICATIONS

ORION TELESCOPE & BINOCULARS INTELLISCOPE XT10

- 10-inch f/4.7 Newtonian reflector
- Dobsonian mount
- 2" rack-and-pinion focuser with 1¼" adapter
- Sirius Plössl 25mm (48x) and 10mm (120x) eyepieces
- 9x50 straight-through finder scope
- Collimation cap
- Eyepiece rack

Total weight, assembled:
55 pounds, 4 ounces (25.1 kg)

Price:
$649

OPTIONAL INTELLISCOPE COMPUTERIZED OBJECT LOCATOR

- Database with more than 14,000 celestial objects
- Backlit, two-line liquid-crystal display

Size/weight:
5.5" by 3.5" by 1.2" (14 by 9 by 3 centimeters)/10 ounces (0.28 kg)

Price:
$149

Everything is powered by one 9-volt battery (supplied), which showed no sign of needing to be replaced after many hours of use. As Orion points out, the mount uses no motors — you push the XT10 to the position indicated by the COL. Thus, power requirements are minimal. Orion provides a Velcro strip so when you're not using the COL, you can attach the handset to the tube or mount wherever you like. An optional aluminum holster also is available from Orion.

In an effort to make the COL as user-friendly as possible, Orion designed it to require the minimum amount of input from the user at power-up time. You don't need to know your latitude and longitude or enter the date to locate the vast majority of the objects in the database. Just switch it on, point the XT10 at the zenith, and locate two readily identifiable alignment stars. If you're not sure about finding your way around the sky, the manual

Adrian Ashford *is a British observer who, between telescope reviews, takes a keen interest in lunar and planetary phenomena.*

shows seasonal all-sky maps for the Northern Hemisphere with alignment stars clearly indicated. A map for the Southern Hemisphere is sure to follow.

Precise initial targeting of alignment stars is vital for the handset to create a model of the sky, and the unit will tell you how accurate your pointing was in the form of a "warp factor": The smaller the number, the better your setup and the easier it will be for the computer to lead you to subsequent objects.

The COL reads positional data from optical encoders located on both axes of the mount. Each encoder is capable of measuring the telescope's position to 0.04° — an angle equivalent to the width of a quarter seen from 39 yards (35½ meters). I found the axes of the mount were orthogonal to a high degree of accuracy, so I easily achieved warp factors under 0.2°.

Observers may choose from more than 14,000 objects in the COL's already programmed database: 837 stars, including doubles and variables; 7,840 NGC objects; 5,386 IC objects; 110 Messier objects; 12 monthly tours; and 8 major planets. If that's not enough, there's memory to add your own 99 objects. Navigating this enormous amount of information requires a cleverly designed series of menus, and the COL's system lets you find what you're looking for quickly and easily. You can access the main object categories — nebula, cluster, galaxy, planet, etc. — with a single button-press.

Once you've selected an object, the system lists its position and brightness and provides a scrolling description. The top line of the display gives a continuous readout of the distance you have to move the IntelliScope in altitude (up and down) and azimuth (side to side) in order to center the object. And you don't have to know anything about angular measurements — just move the XT10 in the directions indicated by the arrows. When the object is less than 10° from centered, the screen displays its distance in ⅒° increments. The object will be in your field of view when both indicators display 0.0.

The system works in reverse, too. Let's say you were sweeping around the sky and came across a faint, fuzzy object. Press the ID button, and you're given the option to identify a star, nebula, galaxy, etc. If you're not sure, opt for "any." The COL searches its database and displays the object nearest to where the scope is pointed.

Problems are minor and do not detract from the enjoyment of the package. The first concerns the COL's power-on button. It doesn't have quite the same tactile feel as the others on the keypad, and if not pressed squarely, it can become temporarily stuck under the edge of the casing.

I include the following more as a tip than a problem. Because there's no option to enter the time, it's advisable to add one day onto the date when observing late into the night for improved planetary pointing accuracy. The COL seems to generate planetary positions for the start of the date in question, which means fast-moving objects like Mercury may otherwise be outside the field of view.

The power-saving feature that turns the handset off after 15 minutes of inactivity may be a problem for some users. When the power-saver activates, the XT10 loses its alignment. I'm hoping a software update will address this because it would be useful to align the IntelliScope just before dawn and "leave the clock running" for locating planets or bright stars in the daytime.

A great combination

I was impressed by the performance of Orion's IntelliScope XT10 and Computerized Object Locator as an integrated system. Target location was as accurate as any other digital setting-circle system I've tested and easier to use than most. Rapid slewing doesn't seem to confuse the encoders either. Objects were always in the central half of a low-power eyepiece's field of view. The COL is also reliable: It never crashed or locked up in all the hours of testing.

Given that the latest version of the basic SkyQuest XT10 uses a tube assembly virtually identical to the IntelliScope XT10's, is the new scope worth the extra $100? The answer is an unequivocal "yes" because the new mount is superior. Also, even if you don't purchase the COL now, it's something you will probably want later.

The IntelliScope XT10 is clearly not your father's Dob. The graceful curves of its mount and gorgeous metallic bronze tube are as much a delight to look at as the scope is to look through. Purists may argue that we've lost the spirit of John Dobson's simple design by adding the trappings of computer technology, but I disagree. Orion has produced a product that marries the best aspects of the Dobsonian philosophy with a computerized object-location system — and it's close to a perfect union. A

THE OPTICAL-TUBE ASSEMBLY of the new IntelliScope XT10 is made of enameled, rolled steel. The tube — including the mirror — weighs only 29 pounds. *ASTRONOMY*: WILLIAM ZUBACK

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8" Schmidt-Cassegrain, w/UHTC ..... **2370**^{00}
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Nagler, 12mm 1.25" and 2" ..... **300**^{00}
Nagler, 16mm 1.25" ..... **270**^{00}
Nagler, 17mm 2" ..... **330**^{00}
Nagler, 20mm 2" ..... **370**^{00}
Nagler, 22mm 2" ..... **390**^{00}
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The finder (6 x 30mm on the 6" and a 9 x 50mm on the 8" and larger scopes) is mounted in an easy-to-align quick release bracket. 8" and larger scopes have a 2" metal rack and pinion focuser (with a 1.25" eyepiece adapter) and a 2" 32mm E-Lux eyepiece is standard. The 6" scope has a 1.25" metal rack and pinion focuser and comes with a 25mm 1.25" Plössl.

The 10" and 12" scopes have a battery-operated fan for cooling their primary mirrors. All have fast cool-down metal tubes and BK7 optical glass mirrors.

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6" f/8 StarHopper ..... **$249**^{00} + $59 freight
8" f/6 StarHopper ..... **349**^{00} + $69 freight
10" f/5 StarHopper ..... **499**^{00} + $79 freight
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Eyepiece cases start at only $2.49. Our bolt-type plastic containers keep your eyepieces free from dew and dust. Foam inserts cradle eyepieces to protect against accidents. **www.astronomics.com** lists which eyepieces fit which containers.

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Galaxies & The Universe: This 112-page soft cover helps you find hundreds of galaxies. Our #A9573. Regularly $19.95, it's sale priced at **$7.95**.

Stars & Galaxies: Our part #A9566. This 200-page hard cover includes 344 of the best deep sky objects. Regularly $29.95, it's sale priced at only **$9.95**.

Universe From Your Backyard: This 188-page hard cover, #A9565, helps you find 690 of the finest deep space objects. Regularly $29.95, it's on sale for only **$14.95**.

LED flashlights start at only $21.95. Red night vision flashlights protect your dark-adapted vision while you're observing.

The **Celestron** variable brightness flashlight (our part #VLED) is **$21.95**. The **Rigel Systems** variable brightness light (#4591), right, is **$24.95**. The **Rigel Systems** two-color variable brightness flashlight (#4592) – a red light for reading star charts, and blue-white for setting up and taking down your scope – is **$29.95**.

The best CCD book is $49.95. Before you spend $3000 on a CCD camera (or even $249), spend **$49.95** on this informative book.

The New CCD Astronomy by Ron Wodaski is the best and most complete imaging reference available for CCD photographers of all skill levels. It includes everything you need to know to become proficient at CCD imaging, plus a free subscription to on-line updates and reference materials.

Vibration suppression pads stop your scope's jitters. Put these handy pads under the legs of your telescope or spotting scope tripod and you'll virtually end the tremors that blur your view for a few seconds each time a breeze comes up or you touch the scope to focus. A set of three **Celestron** vibration suppression pads, our part #VSP, costs **$49.50.** The set of three **Meade** vibration isolation pads shown right, our part #895, costs **$49.95.** Both sets dramatically improve your observing and are well worth the modest investment.

Gifts from $50 to $100 . . .

Power to the people! Buy one Power Tank instead of hundreds of flashlight batteries. **Celestron Power Tank** rechargeable 12-volt batteries have the power you need to run your telescope and accessories all night long, and can be recharged hundreds of times. That will save you hundreds of dollars over the cost of constantly buying flashlight batteries every few weeks. Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank shown, our part #4512V, is only **$59.95**. The 17 amp hour Power Tank, our #4517V, is sale priced at only **$89.95**.

Gifts from $100 to $200 . . .

The sky is yours for $129! Actually, it's the **TheSky6** ***Serious Astronomer Edition*** from **Software Bisque**, It's the latest version of the most popular star-charting software around. With over 20 million stars and over a million deep space objects, it generates the most realistic and detailed graphical rendition of the night sky ever. It looks so real you'll think you're under the stars themselves.

Get more. Pay less. How much would you pay for a 1/10th wave accuracy 97% reflectivity 2" enhanced aluminum mirror star diagonal and a 1.25" eyepiece adapter? Some competitors charge up to $250 for that combination. But the **William Optics** 2" diagonal, our part #W2, is only **$130**!

The **William Optics** 2" rotatable Schmidt-Cassegrain zero image shift Crayford-style manual focuser with 1.25" eyepiece adapter below, our part #WSCTF, is only **$149**. As with all William Optics scopes and accessories, it offers exceptional value – fine optical performance and quality mechanics, at a price that's less than the competition.

Why look at a map when you can look at the sky? When skies are cloudy, you can spend your next evening's observing with the help of a star chart – or you can use **The Desktop Universe** from **Main Sequence Software**. This **$199.95** software program was named the leading Hot New Product by *Sky & Telescope* magazine. While it has all the standard star-charting features of a state-of-the-art planetarium program, it plots your charts on a seamless all-sky photographic CCD mosaic of nearly 20,000 images. You don't see lines and symbols on a blank page. You see the actual sky itself. *Sky & Tel* suggested, "It just might be the biggest advance in portraying the night sky since the paintings on the ceilings of Egyptian tombs."

Burgess wide angle eyepieces start at $29? Incredible.

Take out the frills, like fancy boxes and and engraved barrels, but leave in the optical performance. What do you get? Wide angle eyepieces priced far too low for the image quality you get. **Burgess Optical** eyepieces set new standards for eyepiece value. Great for scopes or binoviewers.

Wide angle, 1.25", 60° field, 8mm or 12mm	**$29**.00
Wide angle, 1.25", 17mm 65° or 21mm 67°	**39**.00
Set of all 4 wide angle	**99**.00
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Super wide, 2", 72° field, 26mm or 32mm	**69**.00
Super wide, 2", 70° field, 38mm	**69**.00
Set of 4 super wide, three 1.25", one 2"	**199**.00
Set of all 6 super wide	**299**.00

Quantities are limited at these low prices.

Nifty new Meade Series 5000 eyepieces.

Meade's brand-new Series 5000 eyepieces are available with 20 models using three advanced optical designs.

The seven new Plössls use a five and six element design and range from a high power 1.25" 5.5mm to a 2" 40mm. Each has a wide 60° field of view. Prices range from $89 to $199.

The new six-element Super Wide Angles all have a 68° field. There are six models – from a 1.25" 16mm at $179 to a big 2" 40mm at $399.

There are seven new Ultra Wide Angle eyepieces using a six or seven element design. Each has a very wide 82° field. They range from a 1.25" 4.7mm for $199 to a 2" 30mm at $449.

Each has long eye relief, a twist-up rubber eyecup, and very good images.

and a new and improved website at www.astronomics.com!

We've added more products and features to our website. There are calculators – for CCD cameras, eyepieces, Barlows, camera adapters, and more. You can do side-by-side product comparisons. Looking for a particular product? Our site tells you if it's in stock and if we have a used one to save you money. And there are more expanded website features in store for you.

Celestron 11" scopes start at only $1699.

An 11" Celestron **Advanced Series** Schmidt-Cassegrain makes big aperture astronomy affordable. With almost twice the light-gathering of an 8" scope, it shows you more deep space objects than an 8" fork mount – *for about the same price.*

Celestron 11" scopes put multicoated optics on easy-to-use equatorial and computerized go-to mounts. The scopes available from our stock include:

C11S on an equatorial mount	**$1699**.00
C11S with XLT coatings	**1979**.00
C11S-GT go-to equatorial	**1999**.00
C11S-GT go-to with XLT coatings	**2279**.00

The C11S and C11S (XLT) have an adjustable height tripod with 2" steel legs, slow motion controls, setting circles, 40mm Plössl eyepiece, and a 9 x 50mm finder. Starbright multicoatings are standard on the C11S. State-of-the-art XLT multicoatings on the C11S (XLT) give you 16% more light. An optional dual-axis drive is available to motorize each scope.

The GT (go-to) models add dual motor drives and a NexStar computer that automatically finds and tracks over 45,000 stars and objects.

They are easy to transport and set up (the heaviest piece weighs only 29 lbs.) And, best of all, they are very affordable. A big scope no longer costs a fortune, thanks to Celestron.

$1699

Celestron's NexImage captures the solar system for only $99.

There's a true CCD at the heart of Celestron's NexImage Solar System Imager. It's a Sony HAD full color 640 x 480 CCD with 5.4 micron pixels. It takes high power lunar/planetary images with any brand and size telescope and sends them to your computer to view live or print out later. At only $99, it makes serious solar system imaging affordable for everyone.

Meade Deep Sky Imager (DSI) for $299.

The Meade DSI electronic camera takes long exposure deep sky photos in full 16-bit color at a fraction the cost of a CCD camera. It works with any telescope to take stunning deep sky photos of galaxies, nebulas, and star clusters (as well as sharp solar system shots).

The easy-to-use Meade Deep Sky Imager includes the renowned Autostar Software Suite planetarium/imaging program and USB cables to connect the imager to your laptop or PC. Best of all, the entire package is all yours for only $299!

Is this your last chance to save on a Takahashi apo?

To be honest, we don't know how much longer Takahashi can keep running this sale on their superb **Takahashi** *fluorite apochromatic* refractors. We suspect it may all be over at the end of the year. This may be your last chance to save a bundle on a Tak doublet apo optical tube.

The outstanding 3.1" **FS-78** f/8 optical tube is on sale for **$1195!** You save $184!

The compact 90mm f/5.6 **Sky 90 II** is only **$2065!** You save $414! *Sky & Tel* called it "an ideal travelscope for mobile observers, providing maximum performance at minimum size."

The latest 4" **FS-102 II** f/8 with sliding dew shield is **only $2095**! You save $454!

Only $4495 lets you own an **FS-128** 5" f/8! This sale saves you $754!

Finally, the 6" f/8 **FS-152** is **only $6995**! You save $2334!

We also stock the 22" **FSQ-106N** 4" f/5 four-lens *dual fluorite* astrograph apo with a 4" focuser, shown to the left.

If you want a premium fluorite apo refractor at a money-saving sale price, and you want it right now, the scope you want is a Takahashi from ***astronomics***.

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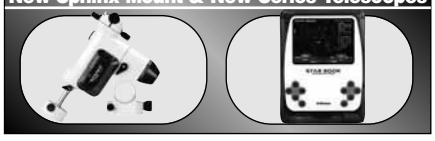

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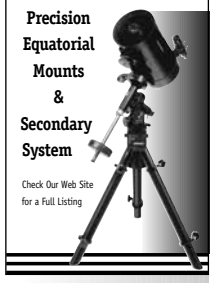

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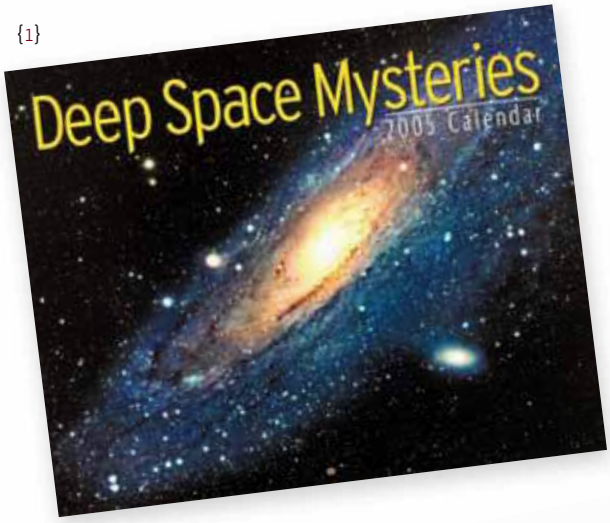

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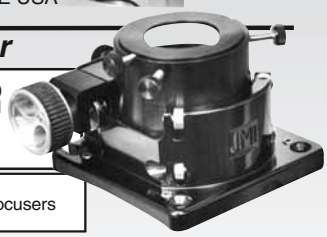

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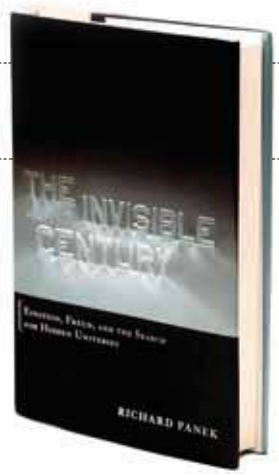


Down at the corner of Einstein and Freud

The Invisible Century

Richard Panek, 258 pages, Viking Penguin, New York, 2004; ISBN 0–670–03074–0; hardcover, $24.95

At the turn of the 20th century, quiet revolutions began in two disparate areas of science. Behind these were two men, each a colossus. Sigmund Freud expanded the concept of the mind from the familiar consciousness to a furtively powerful subconscious. Albert Einstein, meanwhile, began linking space and time with his concept of relativity. The two initiated ideological sea changes and sparked the development of entirely new fields: cosmology and psychoanalysis.

For Richard Panek, Einstein and Freud are distinguished not only in their ideas but how they conceived them. In *The Invisible Century,* he links the two men, rarely thought of together, via their thought processes. He argues that unlike those before them, Freud and Einstein based discovery on internal reasoning, not external observation.

Pairing them in a single book, however, does seem a little artificial. Einstein and Freud met once and had, in Freud's words, "a very pleasant talk." But they did not become friends, nor was either man ignited by the other's passions. Nonetheless, they shared a good portion of the same century, during which monumental ideas of their respective fields were born.

While the stories of Einstein and Freud may appear stitched together for the book, the stories of their internal lives make an intriguing quilt. If the two men's ideas deified them in both science and the public mind, it's compelling to be reminded that Einstein and Freud were still just men. As Panek explains their reasoning, he points out that possession of genius hardly precluded arrogance, uncertainty, frustration, and lingering doubt.

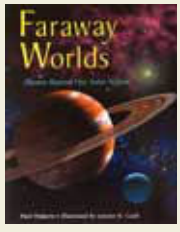
Both Einstein and Freud made false starts, fired letters at friends who acted as sounding-boards, recanted hastily claimed breakthroughs, and finally, refashioned existing knowledge into new concepts. Their ideas were revolutionary because, in part, as both Einstein and Freud saw, the truths others had looked for in vain had been masked by people asking the wrong questions.

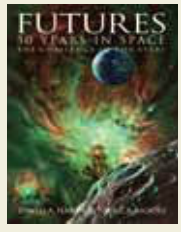
Panek helps us understand how layers of scientific and philosophical ideas led to Freud and Einstein's breakthroughs. Panek sweeps past Ptolemy and Copernicus, then lingers on Galileo, Kepler, and Newton. A similar, if less familiar, pantheon of psychology and neurology greats appears as Freud gropes to understand the mind.

Panek also shares the men's triumphs, as when Einstein's calculations using his new theory of relativity suddenly jibe perfectly with numbers describing the unusual motion of Mercury: "Something burst inside him . . . his heart began beating erratically, as if the irregularity that he'd banished from the heavens with a few strokes of his pen had taken refuge in his rib cage." Mercury gave Einstein proof in the space-time pudding that space itself was bendable.

Panek wants us to understand these two intellects didn't piece together theories from painstaking research. Both tapped current knowledge, but their ideas grew mostly within their minds. When all factors were finally in place, Einstein and Freud gave birth to fully formed theories, but like an infant, the gestation of these ideas was largely hidden — or "invisible."

If joining the two tales is a little forced, Panek's presentation of how these men forged their theories makes for challenging and engaging reading. **— JESSA FORTE NETTING** *is a science writer who brings scientists' hidden ideas into light in New York City.*





Faraway Worlds

Paul Halpern, 32 pages, Charlesbridge Publishing, Watertown, Massachusetts, 2004; ISBN 1–57091–616–0; hardcover, $16.95.

Illustrated by Lynette Cook, this book introduces children to extrasolar planets and solar systems. The text and illustrations show how astronomers discover these worlds, and the artwork shows imaginary scenes on them.

Futures: 50 Years in Space

David A. Hardy, Patrick Moore, 112 pages, Harper Design International, New York, 2004; ISBN 0–06–073038–2; hardcover, $24.95.

Space artist David Hardy and astronomy writer Patrick Moore team up to present different views of the universe as conceived over the last half-century. The text explains what ideas lay behind now-outmoded earlier concepts. Roughly the latter third of the book ventures beyond the solar system to portray stars, nebulae, and galaxies.

Sharing the Night Sky

John York, 114 pages, StarPartyGuide.Com, El Paso, Texas, 2004; paperback, $12.95. [w] www.starpartyguide.com

This self-published book (laser printed and coil-bound) is not a guide to starting or running a star party but rather a guidebook you'd use *at* a star party. The book's first half presents Moon maps and descriptive lists of sights worth finding. The latter half has deep-sky finder charts for the brightest Messier and NGC objects, plus pretty double and multiple stars.

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102 Package

Tube: 4" Ivory • f/: 8.6 • Focuser: 2" • Case: Hard
Diagonal: 2" • Everbrite • Eyepiece: 20 Plossl

NP 101

Tube Color: Ivory• f/: 5.4• Focuser: 2"
Diagonal: 2" Everbrite • Case: Hard

102 Package $2,635
102i Package $3,580
NP 101 ..... $3,595
TeleVue 85 Package $2,080
TeleVue 76 Package $1,675
Pronto Package $2,080
Ranger Package $760

EYEPIECES

Many of the following prices are a result of a Factory Authorized Sale and expire December 31, 2004.

PLOSSLS

55mm ..... $228 **20mm** ..... $95 **40mm** $110
15mm ..... $82 **32mm** ..... $110 **11mm** $82
25mm ..... $95 **8mm** $82

RADIAN

18mm $199.95 **8mm** ..$199.95
14mm ..$199.95 **6mm** ..$199.95
12mm ..$199.95 **5mm** ..$199.95
10mm ..$199.95 **4mm** ..$199.95
3mm $199.95

NAGLER

31mm Type 5 ..... $530 **12mm Type 4** $300
26mm Type 5 ..... $490 **9mm Type 6** $240
22mm Type 4 ..... $390 **7mm Type 6** $240
17mm Type 4 ..... $330 **11mm Type 6** $240
16mm Type 5 ..... $270 **5mm Type 6** $240
13mm Type 6 ..... $240 **3.5mm Type 6** $240

ZOOM

3-6mm ..... $380 **8-24mm** $210

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2x Powermate ..... $280 **5x Powermate** $168
2.5x Powermate ..... $168 **2x Barlow** $105
4x Powermate ..... $295 **2x Big Barlow** $198
3x Barlow $105

ACCESSORIES

Ash Panoramic Mount $495
Ash Gibraltar Mount $595
Ash Panoramic w/SkyTour installed $1205
Ash Gibraltar w/SkyTour installed $1365
BinoView $1030
Eyepiece Carrying Bag $125
90° Everbrite Diagonal- 1.25" $190
60° Everbrite Diagonal- 1.25" $210
45° Erecting Prism $60
Camera Adapters- 1.25"/2" $45
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NexStar 11 GPS .... $3,224 **NexStar 11 GPS XLT** $3,504
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NexStar 8i Kit ..... $1,379 **NexStar 8i Kit XLT** $1,529
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NexStar 76 GT ..... CALL **NexStar 102 GT** ... CALL

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StarHopper 10 ..... $499.95
StarHopper 12 ..... $849.95

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Firstscope 76 EQ $139.95
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Firstscope 80 EQ $229.95
Firstscope 102 AZ 102mm (4"), 1,000mm f/10 $329.95
Firstscope 114 EQ 114mm (4.5") $219.95
Firstscope 114 Short $154.95

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Power Tank $65

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Eyepiece Filter Set (94119-20) w/12, 25, 56, ND-25 ..$49
Eyepiece Filter Set (94119-30) w/23A, 38A, 58, ND-50 $49
Eyepiece Filter Set (94119-40) w/8, ND-13, 47, 82A ...$49
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Moon Filter 1.25" $19

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C10-N 10" Reflector, 1200mm f/4.7 ..... $909

COMPUTERIZED

C5-S GT 5" Schmidt-Cassegrain, 1250mm f/10 .... $1,099
C6-R GT 6" Refractor, 1200mm f/8 ..... $1,069
C8-N GT 8" Reflector, 1000mm f/5 ..... $1,019
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C90 Mak ..... CALL **C130 Mak** ..... CALL

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E-Lux 25mm, 1.25" $29.95 **E-Lux** 40mm, 1.25" $34.95
E-Lux 26mm, 2" ... $54.95 **E-Lux** 32mm, 2" ... $59.95
E-Lux 40mm, 2" $64.95
Omni 4mm, 1.25" .. $39.95 **Omni** 6mm, 1.25" $39.95
Omni 9mm, 1.25" .. $39.95 **Omni** 12.5mm, 1.25" $39.95
Omni 15mm, 1.25" $39.95 **Omni** 20mm, 1.25" $39.95
Omni 25mm, 1.25" $39.95 **Omni** 32mm, 1.25" $49.95
Omni 40mm, 1.25" $49.95 **Omni** 2x Barlow .. $39.95
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X-Cel 8mm, 1.25" .... $64 **X-Cel** 10mm, 1.25" $64
X-Cel 12.5mm, 1.25" ... $64 **X-Cel** 18mm, 1.25" $64
X-Cel 21mm, 1.25" .... $64 **X-Cel** 25mm, 1.25" $64
Ultima 5/7.5mm, 1.25" $75 **Ultima** 10mm, 1.25" .. $75
Ultima 12.5mm, 1.25" $75 **Ultima** 18mm, 1.25" .. $75
Ultima 30mm, 1.25" .. $90 **Ultima** 35mm, 1.25" $105
Ultima 42mm, 1.25" ... $90 **Ultima** 2x Barlow $75
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Axiom 23mm, 1.25" .. $149 **Axiom** 19mm, 2" $175
Axiom 34mm, 2" ..... $205 **Axiom** 40mm, 2" $255
Axiom 50mm, 2" $275

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- **Heavy-duty tripod** with ultra-sturdy 2" stainless steel legs, center brace and accessory tray for superior stability, rigidity and vibration dampening
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- **Proven NexStar computer control system** used in our most sophisticated GoTo telescopes
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- **Automatically tracks** any celestial object as it moves through the night sky
- **Hibernate feature** maintains alignment while scope is powered down

Auxiliary ports for Hand Control, Dec Motor and AutoGuider.

C11-SGT (#11067)

Advanced Features for Astrophotography

- **Programmed polar alignment** feature walks you through the steps of aligning the telescope to the Earth's axis which is required for astrophotography
- **Autoguider Ready** – mount has a designated autoguider port for long exposure astrophotography
- **Precise GoTo** ensures that hard to find objects are centered in the field of view with higher accuracy

Expandable GoTo Systems – Optional accessories

- **GPS compatible** for even quicker and easier setup, Advanced GoTo models can also be upgraded to GPS scopes with the optional CN16 GPS Accessory Kit (#93966). Kit contains the CN16 GPS module, bracket and holder, and Auxiliary Port Expander
- **NexRemote remote control software** (#93710) allows alignment and operation of Advanced Series GT telescopes from a PC or laptop

For more information on Celestron's Advanced Series models, visit www.celestron.com.

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WHAT'S IN A NAME?

Here's a quick guide to identifying the various types of Celestron Advanced Series telescopes:

S = Schmidt-Cassegrain
N = Newtonian
R = Refractor
GT = Computerized GoTo

Example: C10-NGT
10" Newtonian on a computerized mount.

Item No.	Model	Price + S&H
11067	C11-SGT	$1,999 + 125
11066	C11-S	$1,699 + 105
11048	C10-NGT	$1,199 + $95
11047	C10-N	$909 + $75
11046	C9¼-SGT	$1,779 + $105
11045	C9¼-S	$1,469 + $85

Item No.	Model	Price + S&H
11026	C8-SGT	$1,359 + $95
11025	C8-S	$1,059 + $75
31062	C8-NGT	$1,019 + $85
31061	C8-N	$699 + $65
21020	C6-RGT	$1,069 + $95
21019	C6-R	$849 + $75

Item No.	Model	Price + S&H
31056	C6-N	$399 + $50
31053	C6-N HD	$529 + $50
31054	C6-NGT	$799 + $70
11072	C5-SGT	$1,099 + $75
11071	C5-S	$849 + $65
21016	C4-R	$399 + $40

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22.0	Nagler	Type 4 $390.00	11.0	Nagler	Type 6 $240.00	14mm	Radian	$199.95
20.0	Nagler	Type 5 $370.00	9.0	Nagler	Type 6$240.00	12mm	Radian	$199.95
17.0	Nagler	Type 4 $330.00	7.0	Nagler	Type 6 $240.00	10mm	Radian	$199.95
16.0	Nagler	Type 5 $270.00	5.0	Nagler	Type 6 $240.00	8mm	Radian	$199.95

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- Variable tension clutch system for proper balance and control in both altitude and azimuth.
- Optical quality BK7 annealed glass provides better thermal expansion properties than standard plate glass mirrors.
- Built-in cooling fan improves mirror cooling time and reduces damaging tube currents (for StarHopper 10" and 12" models).
- 9-point flotation mirror cell gives equal support of the primary mirror to minimize mirror deflection (for StarHopper 10" and 12" models).

Built-in cooling fan for 10" and 12" models

Specifications	StarHopper 6	StarHopper 8	StarHopper 10	StarHopper 12
Model Number	10600	10800	10110	10112
Primary Mirror	6"	8"	10"	12"
Focal Length	48"	48"	50"	60"
Eyepiece	25mm–1-1/4"	25mm–1-1/4"	32mm E-Lux™ 2"	32mm E-Lux™ 2"
Finderscope	6 x 30	9 x 50	9 x 50	9 x 50
Focuser	1-1/4"	2" with 1-1/4" adapter	2" with 1-1/4" adapter	2" with 1-1/4" adapter
Suggested Price*	**$299.00**	**$399.00**	**$549.00**	**$899.00**

* Prices shown are suggested U.S. mail order prices.

For more information about StarHopper Dobsonian telescopes and the complete selection of Celestron telescopes and accessories, binoculars, and sport optics, visit: **www.celestron.com**

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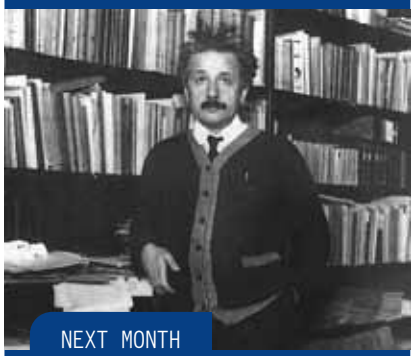

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Cassini explores Titan

The Cassini spacecraft has just made its first close pass by Saturn's haze-shrouded moon. Learn what Cassini discovered, and what it portends for the imminent touchdown of the Huygens probe.

Mr. Eclipse

Meet Fred Espenak, a globetrotting NASA astrophysicist who has observed 17 total solar eclipses.

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05.01.05–05.08.05

While springtime may seem far away,

especially for those living in chillier areas of the Northern Hemisphere, the deadline for entering the Texas Star Party (TSP) registration lottery is January 17. Being one the most popular North American star parties with the amateur

TOURS OF McDONALD OBSERVATORY for TSP attendees include visits to the domes housing the Otto Struve Telescope (center), Harlan J. Smith Telescope (right), and the largest instrument at the facilities, the 9.2-meter Hobby-Eberly Telescope (left). MARTY HARRIS/McDONALD OBSERVATORY

astronomy community guarantees the TSP organizers many applications.

Held at the Prude Ranch, near Fort Davis, Texas, the star party is known for its no-nonsense observing atmosphere. To ensure this high-quality experience, attendance is limited to 700.

Besides skywatching, activities include behind-the-scenes tours of McDonald Observatory, lectures, workshops, imaging, competitions, and a swap meet.

If you miss entering the drawing for visitor passes, a few openings may occur after the deadline.

For more information, e-mail the TSP registrar at tspreg@texasstarparty.org; web site, *www.texasstarparty.org*.

THROUGH MAY 2005

Solar Fireworks

Newark Museum, Newark, New Jersey. Designed by astronomers at the Newark Museum and the New Jersey Institute of Technology, this exhibit features hands-on activities and information on the Sun's composition. For more information, visit *newarkmuseum.org/planetarium*.

01.13.05

Connacht Star Party

Westwoodhouse Hotel, Galway City, Ireland. Hosted by the Galway Astronomy Club, this year's theme is "Exoplanets." The star party will feature prominent speakers from Ireland and the United Kingdom. For more information, visit *www.galwayastronomyclub.ie.*

01.13.05–01.23.05

Saturn: Jewel of the Solar System

Exploratorium, San Francisco. The museum will provide special coverage of the latest from the Cassini-Huygens spacecraft voyage and study of Saturn. Visit the exhibit to ask questions of mission experts, examine new images, and discover

how our understanding of the ringed planet and its moons has evolved. If you are unable to go to the museum, you may watch live web casts on their site. For more information, visit *www.exploratorium.edu*.

02.02.05–02.06.05

Deep South Texas Stargaze

Escondido Ranch, McMullen County, Texas. Hosted by the Kingsville Astronomical Society, this gathering is held under nearly 7th-magnitude dark skies. Climate-controlled bunkrooms with showers are available as well as camping and RV sites. In addition to observing, there will be speakers and door prizes. For more information, visit *www.geocities.com/kingsville*.

02.07.05–02.12.05

Winter Star Party

Camp Wesumkee, West Summerland Key, Florida. Sponsored by the Southern Cross Astronomical Society. The 12-hour observing sessions at this dark-sky site will provide ample time to target celestial beauties. *Astronomy* assistant editor Matt Quandt will attend. For more information, visit *www.scas.org*.

02.09.05–02.13.05

Orange Blossom Special Star Party

Alafia River State Park, Lithia, Florida. The new site has been entirely reserved for star-party attendees. Register before December 31 to avoid a late fee. For more information, call 813.792.0721; e-mail, dnefarr@msn.com; web site, *home1.gte.net/hoffmanc*.

03.09.05–03.13.05

Kisatchie Star Party

Kisatchie National Forest, near Natchitoches, Louisiana. Sponsored by the Baton Rouge Astronomical Society, this is the fifth annual gathering. The remote, central-Louisiana site guarantees dark skies. Non-astronomy activities include camping, hiking, canoeing, and fishing. For more information, visit *www.bro.lsu.edu/bras/kisatchie.html*.

03.13.05–03.15.05

South Pacific Star Party

Wiruna, near Ilford, New South Wales, Australia. Hosted by the Astronomical Society of New South Wales, this site offers great dark skies. The location, featuring many species of exotic birds, wombats, kangaroos, and other wildlife, is a nature-lover's paradise. For more information, visit *www.asnsw.com/spsp*.

03.31.05–04.14.05

Astronomy's Total Solar Eclipse Tour of the Galapagos

Various locations, Galapagos Islands. View an amazing astronomical event while cruising the exotic Galapagos. Join *Astronomy* magazine editor Dave Eicher and astronomers Jay M. Pasachoff and Fred Espenak on a cruise of the islands as they view the total solar eclipse of April 8. Besides astronomy-oriented events, this trip includes incredible wildlife viewing, snorkeling, sailing, and scuba diving. For more information, e-mail jen@astronomicaltours.net; web site, *www.tourwithastronomy.com*.

04.02.05–04.16.05

Astronomy's Total Solar Eclipse Tour of Tahiti

Various locations, French Polynesia. *Astronomy* associate editor Michael E. Bakich and eclipse expert Michael D. Reynolds will lead a Tahitian cruise to chase the total solar eclipse of April 8. The boat will be equipped with instruments for astronomical observing. Aboard the ship, attendees can receive underwater photography training to prepare for imaging the gems beneath the ocean's surface. For more information, e-mail jen@astronomicaltours.net; web site, *www.tourwithastronomy.com*.

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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RESOURCES

Learn more about this issue's topics:

THE YEAR IN ASTRONOMY

WEB — (10) An assessment from NOAA's Space Environment Center about the Halloween storms' impact is at *www.sec.noaa.gov/AboutSEC/SWstorms_assessment.pdf*.

(9) Keep tabs on the Genesis science team's progress through a site at NASA headquarters, *www.nasa.gov/mission_pages/genesis/main/index.html*, and the Genesis mission page, *genesismission.jpl.nasa.gov*.

(8) Relive the transit of Venus at *www.vt-2004.org*, a site run by the European Southern Observatory.

(7) Research papers on the Stardust flyby were published in the June 18, 2004, issue of *Science*; see *www.sciencemag.org*. Visit the Stardust mission site at *stardust.jpl.nasa.gov* for images and animations.

(6) Find the latest Saturn images at the Cassini Imaging Central Laboratory for Operations site, *ciclops.lpl.arizona.edu*, and at the Cassini-Huygens home page, *saturn.jpl.nasa.gov*.

(5) The adventures of Mars rovers Spirit and Opportunity are chronicled at *marsrovers.jpl.nasa.gov*. Get updates on Mars Odyssey and the Mars Global Surveyor at *mars.jpl.nasa.gov/odyssey* and *mars.jpl.nasa.gov/mgs*, respectively. Find the European Space Agency's Mars Express site at *www.esa.int/SPECIALS/Mars_Express*.

(4) Find images and video of Dextre, the robot that may get the job fixing Hubble, at *www.mdrobotics.ca/newsframe.html*, but be sure to look under Dextre's formal, if unwieldy, moniker — Special Purpose Dexterous Manipulator (SPDM).

(3) See the original Deep Field and other Hubble shots at *hubblesite.org*.

(2) The Extrasolar Planets Encyclopaedia at *www.obspm.fr/encycl/encycl.html* contains a catalog of exoplanet discoveries claimed so far, updates on their status, links to scientific papers, and more.

(1) To learn more about Sedna and its unique position in the solar system, visit Mike Brown's site at *www.gps.caltech.edu/~mbrown/sedna*.

SECOND LIGHT

ARTICLES — A special section in the January 4, 2004, issue of the journal *Science* covered astronomers' quest to understand the origin of the first stars. Richard B. Larson and Volker Bromm took a somewhat less technical look at the same question in "The first stars in the universe" (*Scientific American*, December 2001).

WEB — An introduction to the development of the first stars starting with the Big Bang is located at the First Stars site, *www.solstation.com/x-objects/first.htm*. Simulations of early star formation by Tom Abel and his colleagues are at *www.astro.psu.edu/users/tabel/GB/gb.html*.

NASA'S VISIONARY

ARTICLE — Read Anne Kinney's article on the Next Generation Space Telescope, "When galaxies were young" (*Astronomy*, May 1998). It provides an insider's look at the telescope's planning stages.

WEB — Visit the Office of Space Science's site, *spacescience.nasa.gov*, and learn more about Kinney, missions underway, and the future plans for this NASA division.

ASK ASTRO

WEB — Ned Wright's cosmology tutorial features a section called "The ABCs of Distances" at *www.astro.ucla.edu/~wright/distance.htm*. He explains 26 techniques that help astronomers determine distances, including those of Cepheid variable stars.

Or hunt for Cepheids yourself with an on-line lab created by Diane Dutkevitch of Northwestern University at *annie.astro.nwu.edu/labs/m100/huntceph.html*.

Craig Wheeler leads the Supernovae Research Group at the University of Texas at Austin. See what the group is up to at *hej3.as.utexas.edu/~www/SN*.

LURE OF THE PLEIADES

WEB — For observational and scientific information about the Pleiades, see the SEDS (Students for the Exploration and Development of Space) site at *seds.lpl.arizona.edu/messier/m/m045.html*. The site also has a biography of Wilhelm Tempel at *www.seds.org/messier/xtra/leos/tempel.html*.

Steven Gibson, who works at the University of Calgary Radio Astronomy Laboratory, maintains a Pleiades site at *www.ras.ucalgary.ca/~gibson/pleiades*. Be sure to check out his "ancient mythology" link. A

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(Required by 39 USC 3685)

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j.	Percent paid and/or requested circulation (15c divided by 15g times 100)	99.84%	99.84%

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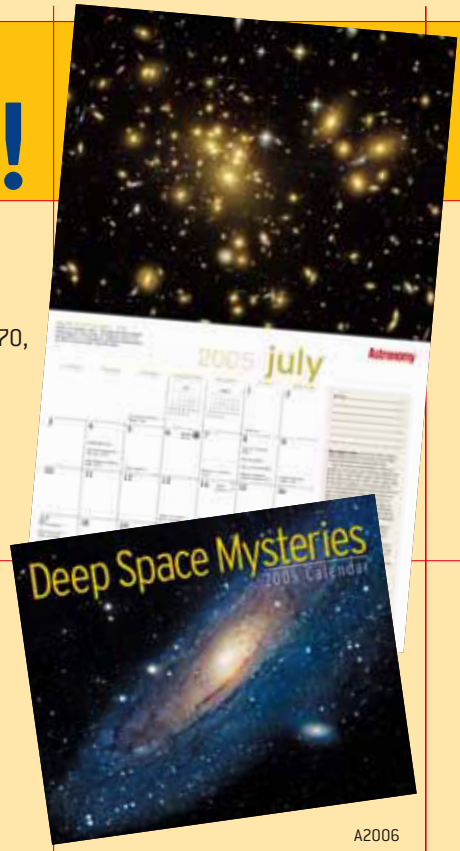

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Reader gallery

Readers share their images ...

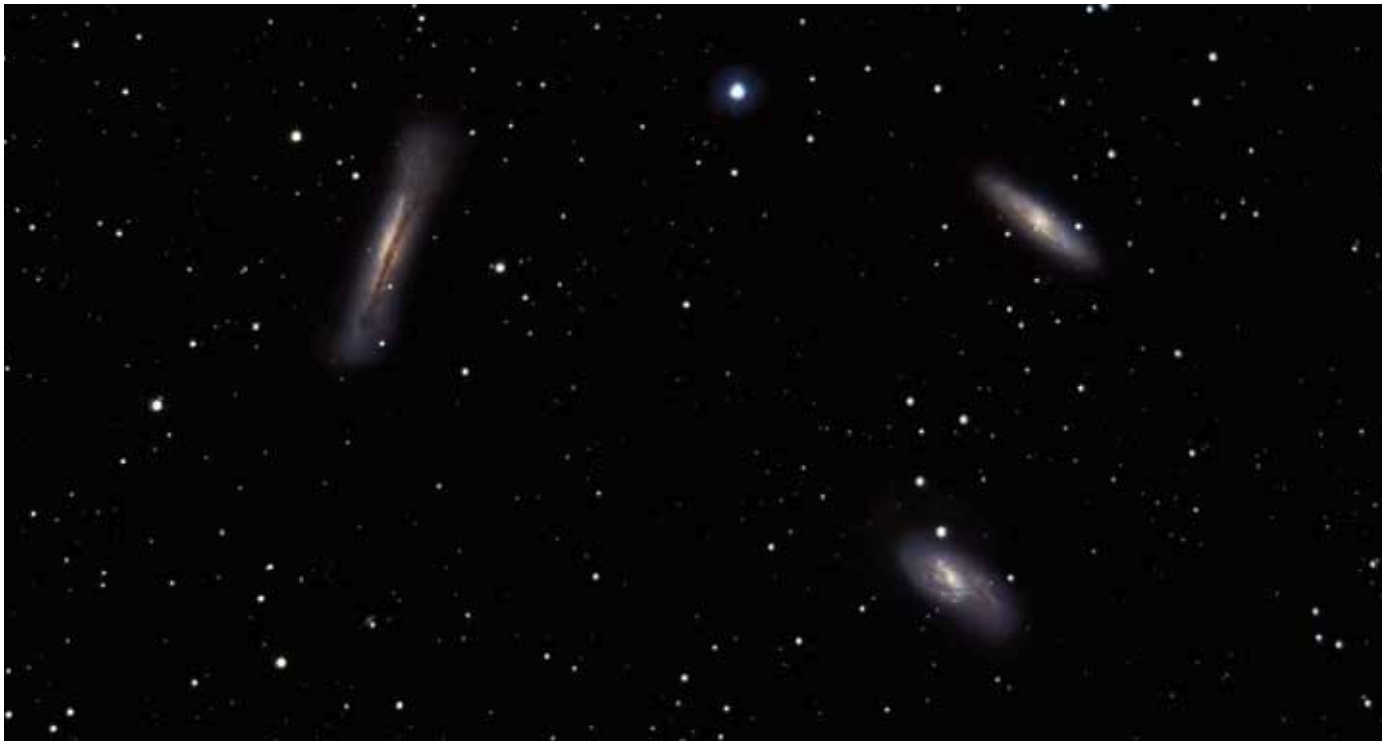
The Dark Tower /// Elliptical galaxy /// Aurora /// A triplet of galaxies
The Cave Nebula /// The Coathanger cluster /// Uranus /// Venus

THE DARK TOWER (4-inch Pentax SDP 105 refractor at f/6.4, Starlight Xpress SXV-H9 CCD camera, Hα/LRGB image with exposures of 30, 120, 15, 15, and 15 minutes, respectively) /// **GERALD RHEMANN AND MICHAEL JÄGER**

A DARK NEBULA

The Dark Tower

The image above of a dark nebula in Scorpius is proof amateur astronomers are using great equipment today. Until recently, this nebula was uncataloged. It doesn't even have an official designation. Dubbed the "Dark Tower," it was shaped by the radiation from the Scorpius OB association, a group of luminous stars that lies near the object. We can almost sense the radiation coming from the bottom left of the cloud, causing gas there to glow red and spreading material from the nebula to the upper right. The Dark Tower lies approximately 5,000 light-years from Earth. A similar — and slightly more famous — object is the Horsehead Nebula in Orion.



Top left, **ELLIPTICAL GALAXY NGC 404 NEAR BETA (β) ANDROMEDAE** (10-inch Orion Optics Newtonian reflector at f/4.8, ATK-2C air-cooled CCD camera, composite of fifty 8-second exposures) /// **RALF VANDEBERGH**

Top right, **AURORA REFLECTED IN BAKER LAKE** (Canon EOS Digital Rebel, 18-55mm lens at f/3.5, set at ISO 1600, 40-second exposure taken July 24 at Baker Lake, Washington) /// **WADE B. CLARK, JR.**

Bottom, **LEO TRIPLET (M65, M66, AND NGC 3628)** (3.6-inch Takahashi Sky 90 at f/4.5, Starlight Xpress SXV-H9 CCD camera, LRGB image with exposures of 120, 20, 20, and 25 minutes, respectively) /// **STEVE CANNISTRA**

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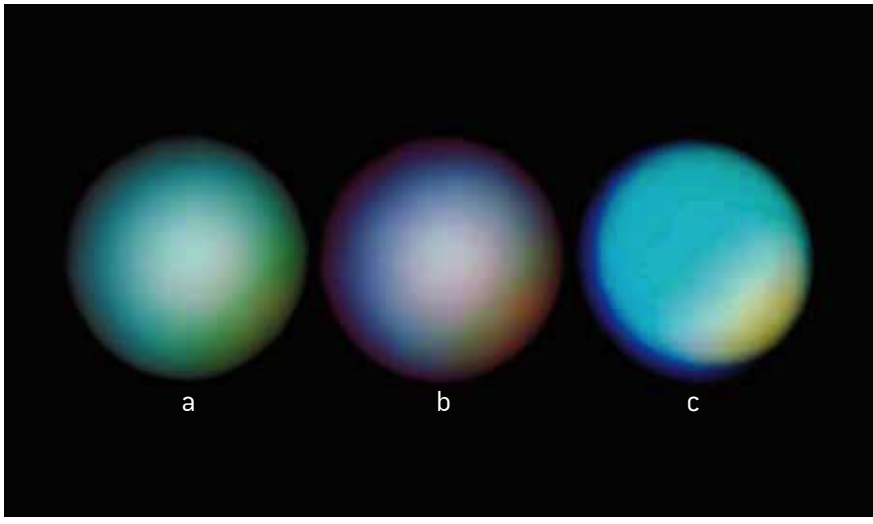
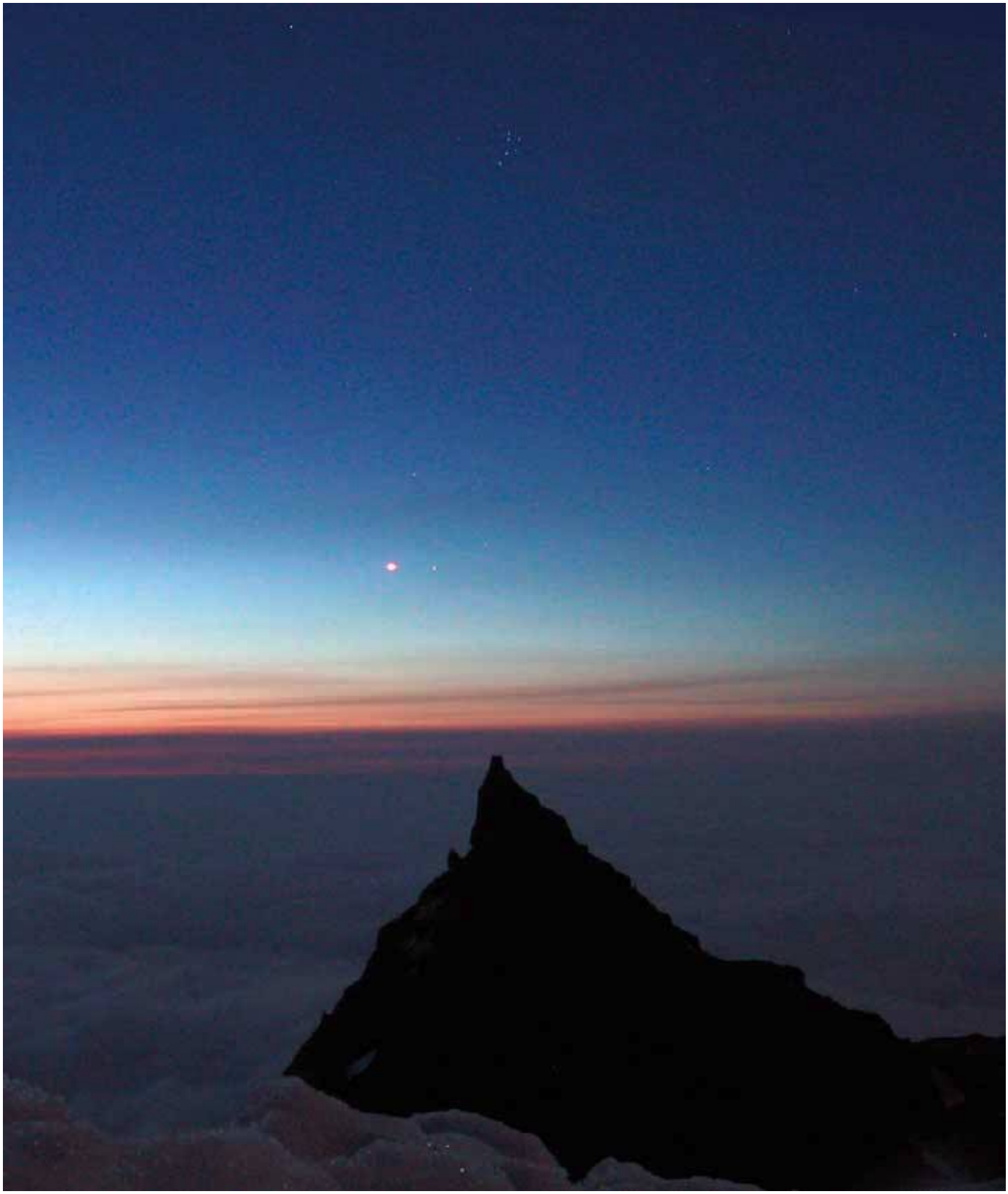


Top, **THE CAVE NEBULA (SHARPLESS 2–155)** (4-inch Takahashi FSQ 106 refractor at f/5.3, SBIG ST-10 XME CCD camera, Hα/RGB image with exposures of 180, 60, 60, and 90 minutes, respectively) /// **DANIEL B. PHILLIPS**

Bottom left, **THE COATHANGER (COLLINDER 399) IN VULPECULA** (8-inch Celestron Schmidt camera at f/1.5, Kodak PJ400 film, four 5-minute exposures digitally combined, taken March 15, 1999, from Payson, Arizona) /// **CHRIS SCHUR**

Bottom right, **URANUS** (10-inch Orion Optics Newtonian reflector at f/24, ATK-2C air-cooled CCD camera, composite of thirty-one 1½-second exposures [a and b] and eleven ½-second exposures [c]) /// **RALF VANDEBERGH**

VENUS AND LITTLE TAHOMA PEAK (Canon PowerShot G1 digital camera at f/2, 8-second exposure taken from Ingraham Glacier, Mt. Rainier National Park, Washington, on July 7) /// **PHILLIP BRACIKOWSKI**



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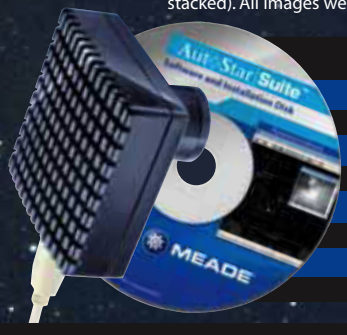
NGC891 Caldwell 23

M27 Dumbell Nebula

M13 Hercules Globular Cluster

M16 Eagle Nebula



SPECIFICATIONS

CCD Sensor	High Sensitivity Sony® Super HAD™ Color CCD
Pixels	510 x 492 pixels (250,000 pixels)
Pixel Size (in microns)	9.6 microns (W) x 7.5 microns (H)
A/D Conversion	16-bit (greater image depth and contrast)
Min. - Max. Exposure Time	1/10,000 of a second to one hour
Housing	Anodized die-cast aluminum
USB Compatibility	USB 2.0 High Speed and USB 1.1
Size / Weight of Product	3.25" x 3.25" x 1.25"/ 10 oz.

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